Booster Notes

Smart Notes, Smart Rank

D. PHARMACY

SUBJECT

BIOCHEMISTRY & CLINICAL PATHOLOGY

Clear Concepts
Better Understanding

Smart Notes
High Score

Biochemistry & Clinical Pathology

Topic 1: Biochemistry का परिचय | Cell की जैव-रासायनिक संरचना

1. Biochemistry क्या है? (What is Biochemistry?)

परिभाषा (Definition): Biochemistry (जैव-रसायन विज्ञान) विज्ञान की वह शाखा है जो जीवित प्राणियों में होने वाली रासायनिक प्रक्रियाओं और रासायनिक पदार्थों का अध्ययन करती है। यह **Chemistry** और **Biology** का संयोजन है।

सरल भाषा में — "**शरीर के अंदर कौन-से रसायन हैं और वे क्या करते हैं**" — यह Biochemistry बताती है।

Biochemistry की प्रमुख शाखाएँ:

शाखा (Branch)	अध्ययन का विषय	उदाहरण
Structural Biochemistry	अणुओं की संरचना — Proteins, DNA, Lipids	DNA double helix संरचना
Metabolic Biochemistry	शरीर में ऊर्जा उत्पादन और रासायनिक परिवर्तन	Glycolysis, TCA Cycle
Enzymology	Enzymes की कार्यप्रणाली	Amylase, Lipase, Pepsin
Molecular Biology	DNA, RNA और Protein Synthesis	Transcription, Translation
Clinical Biochemistry	रोगों का जैव-रासायनिक निदान	Blood Sugar, LFT, KFT Tests

2. Pharmacy में Biochemistry का महत्व (Scope of Biochemistry in Pharmacy)

एक Pharmacist के लिए Biochemistry का ज्ञान अत्यंत आवश्यक है। नीचे इसके प्रमुख क्षेत्र दिए गए हैं:

- **Drug Design एवं Development:** नई दवाइयाँ बनाने के लिए शरीर की जैव-रासायनिक प्रक्रियाओं को समझना ज़रूरी है। जैसे — Insulin का उत्पादन Biochemistry के ज्ञान से संभव हुआ।
- **Drug Metabolism (चयापचय):** शरीर में दवाई कहाँ और कैसे टूटती है — यह जानने के लिए Enzyme activity और metabolic pathways का ज्ञान जरूरी है।
- **Pharmacokinetics:** दवाई का Absorption, Distribution, Metabolism और Excretion (ADME) — Biochemistry पर आधारित है।
- **Clinical Diagnosis में सहयोग:** Pharmacist blood test reports (जैसे LFT, KFT, Lipid Profile) को समझकर रोगी को उचित सलाह दे सकता है।
- **Nutritional Counseling:** Vitamins, Minerals, Proteins और Carbohydrates की जानकारी से Pharmacist मरीज़ों को पोषण संबंधी परामर्श दे सकता है।
- **Biotechnology एवं Biopharmaceuticals:** Recombinant DNA Technology से बनी दवाइयाँ (जैसे — Erythropoietin, Growth Hormone) Biochemistry पर आधारित हैं।
- **Toxicology:** विषाक्त पदार्थों (Poisons) का शरीर पर प्रभाव समझने में Biochemistry सहायक है।
- **Quality Control:** दवाइयों की गुणवत्ता जाँच में Biochemical assays का उपयोग होता है।

Pharmacy में Biochemistry के उपयोग — सारांश तालिका:

क्षेत्र (Area)	Biochemistry की भूमिका
Drug Discovery	Target Enzymes और Receptors की पहचान
Drug Formulation	Stability और Bioavailability का अध्ययन
Diagnostics	Lab Tests — Blood Glucose, Urea, Creatinine
Nutrition Science	Vitamins, Proteins, Minerals का अध्ययन
Pharmacogenomics	DNA-based Personalized Medicine
Biopharmaceuticals	Insulin, Vaccines, Monoclonal Antibodies

3. Cell — जीवन की मूल इकाई (Cell — The Basic Unit of Life)

Cell (कोशिका) जीवन की सबसे छोटी संरचनात्मक एवं क्रियात्मक इकाई है। मानव शरीर में लगभग **37.2 trillion (3.72×10^{13})** कोशिकाएँ होती हैं।

3.1 Prokaryotic और Eukaryotic Cell में अंतर

विशेषता (Feature)	Prokaryotic Cell	Eukaryotic Cell
Nucleus	अनुपस्थित (Absent)	उपस्थित, Nuclear Membrane सहित
आकार	1–10 µm (छोटा)	10–100 µm (बड़ा)
DNA	Circular, Naked (Histone-free)	Linear, Histone-bound
Mitochondria	अनुपस्थित	उपस्थित
Ribosome	70S (50S + 30S)	80S (60S + 40S)
Cell Wall	Peptidoglycan की बनी	Cellulose (Plants) / अनुपस्थित (Animals)
उदाहरण	Bacteria, Archaea	मानव, पशु, पौधे, कवक

4. Cell की जैव-रासायनिक संरचना (Biochemical Organization of Cell)

एक Eukaryotic Cell के प्रमुख घटकों की जैव-रासायनिक भूमिका निम्नलिखित है:

Cell Organelle	रासायनिक संघटक	जैव-रासायनिक कार्य
Cell Membrane (Plasma Membrane)	Phospholipids + Proteins + Cholesterol	Selective permeability — केवल आवश्यक पदार्थों का आवागमन। Fluid Mosaic Model।
Nucleus (केन्द्रक)	DNA + Histones + RNA + Proteins	Genetic information का भंडार। Cell division और Protein synthesis का नियंत्रण।

Mitochondria (माइटोकॉन्ड्रिया)	Enzymes + Lipids + DNA + ATP Synthase	"Power House of Cell" — ATP उत्पादन (Oxidative Phosphorylation), Krebs Cycle।
Ribosomes (राइबोसोम)	rRNA + Proteins (80S)	Protein Synthesis (Translation) — mRNA को Amino Acids में परिवर्तित करता है।
Endoplasmic Reticulum (ER)	Membranes + Enzymes	Rough ER — Protein synthesis। Smooth ER — Lipid synthesis और Drug detoxification।
Golgi Apparatus	Glycoproteins + Enzymes	Proteins की packaging, modification और secretion।
Lysosomes (लाइसोसोम)	Hydrolytic Enzymes (40+)	"Suicide Bags" — पुरानी organelles और बाहरी कणों का पाचन।
Cytoplasm (कोशिका द्रव्य)	Water (70%) + Enzymes + Salts	Glycolysis और अन्य metabolic reactions का स्थल।
Peroxisomes	Catalase + Oxidases	Fatty acid oxidation और Hydrogen Peroxide (H_2O_2) का विघटन।

5. Cell Membrane — Fluid Mosaic Model

Cell Membrane (प्लाज़्मा झिल्ली) की संरचना **Singer और Nicolson (1972)** ने **Fluid Mosaic Model** द्वारा बताई। इस model के अनुसार:

- **Phospholipid Bilayer:** दो परतें — Hydrophilic (जल-प्रेमी) Heads बाहर और Hydrophobic (जल-विरोधी) Tails अंदर।
- **Proteins:** Integral Proteins झिल्ली के भीतर एम्बेड होते हैं; Peripheral Proteins सतह पर होते हैं। ये Transport, Receptors और Enzymes का काम करते हैं।
- **Cholesterol:** Membrane की Fluidity (तरलता) को नियंत्रित करता है।
- **Glycoproteins / Glycolipids:** Cell Recognition और Immune Response में सहायक।

Cell Membrane के रासायनिक घटक:

घटक	प्रकार / मात्रा	कार्य
Phospholipids	लगभग 40–50%	Bilayer बनाते हैं — Membrane की मूल संरचना
Proteins	लगभग 50–60%	Transport, Enzyme activity, Receptors
Cholesterol	Animal cells में अधिक	Membrane fluidity का नियंत्रण
Glycolipids	Outer leaflet पर	Cell-cell recognition
Glycoproteins	Outer surface पर	Antigen के रूप में कार्य — Blood group markers

6. Cell में उपस्थित जैव-रासायनिक अणु (Biomolecules in Cell)

Cell में निम्नलिखित 4 प्रमुख जैव-रासायनिक अणु (Biomolecules) पाए जाते हैं:

Biomolecule	मूल तत्व (Elements)	Cell में स्थान	प्रमुख कार्य
Carbohydrates (कार्बोहाइड्रेट)	C, H, O	Cytoplasm, Glycocalyx	ऊर्जा का प्रमुख स्रोत (4 kcal/g)
Proteins (प्रोटीन)	C, H, O, N, S	Ribosomes, Enzymes, Receptors	संरचना, एंज़ाइम, हॉर्मोन
Lipids (वसा)	C, H, O (P, N)	Membrane, Mitochondria	Membrane संरचना, ऊर्जा भंडारण (9 kcal/g)
Nucleic Acids (न्यूक्लिक एसिड)	C, H, O, N, P	Nucleus, Ribosomes	Genetic information, Protein synthesis

7. Cell में जल (Water) की जैव-रासायनिक भूमिका

मानव शरीर में लगभग **60–70%** जल (Water) होता है। Cell के अंदर जल की मात्रा लगभग **70%** होती है।

➤ **Universal Solvent:** जल में अधिकांश जैव-रासायनिक पदार्थ घुलते हैं।

- **Medium for Reactions:** सभी Metabolic reactions जलीय माध्यम में होती हैं।
- **Temperature Regulation:** जल की उच्च Specific Heat Capacity शरीर का तापमान नियंत्रित रखती है।
- **Transport Medium:** Blood और Lymph में Nutrients, Hormones और Waste products का परिवहन।
- **Hydrolysis:** Proteins, Carbohydrates और Fats का पाचन जल द्वारा होता है।

Eukaryotic Cell के प्रमुख Organelles — आरेख

Cell Membrane → Cytoplasm → Nucleus → Mitochondria → Ribosomes → Golgi Apparatus → Lysosomes → Endoplasmic Reticulum

(Diagram: Eukaryotic Animal Cell — सभी प्रमुख organelles एवं उनके स्थान)

Booster Points (D.Pharmacy Competitive Exam)

- Biochemistry = जैव + रसायन = जीवित प्राणियों में रासायनिक प्रक्रियाओं का अध्ययन।
- Cell को 'जीवन की मूल इकाई' (Basic unit of life) कहते हैं — Robert Hooke ने 1665 में Cell की खोज की।
- Prokaryotic Cell में Nucleus ABSENT होता है; Eukaryotic Cell में Nuclear Membrane सहित Nucleus PRESENT होता है।
- Mitochondria को 'Powerhouse of the Cell' कहते हैं — यह ATP (ऊर्जा) उत्पन्न करता है।
- Lysosome को 'Suicide Bag of the Cell' कहते हैं — इसमें 40 से अधिक Hydrolytic Enzymes होते हैं।
- Fluid Mosaic Model — Singer और Nicolson (1972) ने दिया; Cell Membrane की संरचना बताता है।
- Ribosome — Protein Synthesis का स्थल; Prokaryotic = 70S; Eukaryotic = 80S।
- Smooth ER — Lipid Synthesis और Drug Detoxification; Rough ER — Protein Synthesis।

✦ Cell में 4 प्रमुख Biomolecules: Carbohydrates, Proteins, Lipids और Nucleic Acids।
✦ Pharmacy में Biochemistry का उपयोग: Drug Design, ADME, Clinical Diagnosis, Biopharmaceuticals।
✦ Carbohydrates: 4 kcal/gram; Proteins: 4 kcal/gram; Fats (Lipids): 9 kcal/gram — यह ऊर्जा मान याद रखें।
✦ Glycocalyx — Cell Membrane की बाहरी सतह पर Glycoproteins और Glycolipids की परत — Blood Group markers।

Topic 2: कार्बोहाइड्रेट (Carbohydrates)

1. परिभाषा (Definition)

कार्बोहाइड्रेट (Carbohydrates) वे कार्बनिक यौगिक हैं जिनमें Carbon (C), Hydrogen (H) और Oxygen (O) होते हैं। सामान्य सूत्र: $\mathbf{C_n(H_2O)_n}$। इन्हें **Saccharides** भी कहते हैं। यह शरीर को **4 kcal/gram** ऊर्जा प्रदान करते हैं।

उदाहरण: Glucose ($C_6H_{12}O_6$), Sucrose ($C_{12}H_{22}O_{11}$), Starch $(C_6H_{10}O_5)_n$

2. वर्गीकरण (Classification of Carbohydrates)

वर्ग	परिभाषा	C Atoms	उदाहरण
Monosaccharides	सबसे सरल — Hydrolysis नहीं होता	3C,4C,5C,6C	Glucose, Fructose, Galactose
Disaccharides	2 Monosaccharides + Glycosidic Bond	12C	Sucrose, Maltose, Lactose
Polysaccharides	100+ Monosaccharides — जटिल	$(C_6H_{10}O_5)_n$	Starch, Glycogen, Cellulose

2.1 Monosaccharides — Carbon संख्या के आधार पर

प्रकार	C Atoms	Formula	उदाहरण
Triose	3C	$C_3H_6O_3$	Glyceraldehyde, DHAP
Tetrose	4C	$C_4H_8O_4$	Erythrose
Pentose	5C	$C_5H_{10}O_5$	Ribose, Deoxyribose, Xylose
Hexose	6C	$C_6H_{12}O_6$	Glucose, Fructose, Galactose
Heptose	7C	$C_7H_{14}O_7$	Sedoheptulose

3. रासायनिक गुण (Chemical Properties)

3.1 Reducing एवं Non-Reducing Sugars

Reducing Sugar: Free Aldehyde (-CHO) या Free Ketone (-C=O) group — Fehling's / Benedict's test Positive।

प्रकार	उदाहरण	विशेषता
Reducing Sugars	Glucose, Fructose, Galactose, Maltose, Lactose	Free -CHO/-C=O group; Benedict's Test (+)
Non-Reducing Sugars	Sucrose, Trehalose	कोई free group नहीं; Benedict's Test (-)

3.2 Mutarotation

Glucose जल में घुलने पर α और β रूपों (Anomers) के बीच संतुलन — इसे **Mutarotation** कहते हैं।

Equilibrium: $[\alpha]D = +52.5°$

3.3 Osazone Formation

Glucose + Phenylhydrazine → **Yellow Osazone Crystals**। Glucose और Fructose समान Osazone बनाते हैं।

3.4 Fermentation (किण्वन)

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (Yeast / Zymase enzyme द्वारा — Alcoholic Fermentation)

4. Monosaccharides — संरचना

4.1 Glucose

Glucose (Dextrose / Blood Sugar / Grape Sugar) — Formula: **$C_6H_{12}O_6$ (Aldohexose)**। Normal Blood Glucose = **70–110 mg/dL (Fasting)**

- ➤ Open Chain: Fischer Projection (Aldehyde Group C1 पर)
- ➤ Cyclic Form: Haworth Projection — Pyranose Ring (6-membered)
- ➤ α-D-Glucopyranose (OH C1 पर नीचे) और β-D-Glucopyranose (OH C1 पर ऊपर)

गुण	Glucose का मान
Chemical Formula	$C_6H_{12}O_6$
Molecular Weight	180 g/mol
Type	Aldohexose
Optical Rotation	Dextrorotatory (+52.5°)
Taste	मीठा (Sweet)
Benedict's Test	Positive (Reducing Sugar)
Fermentation	हाँ — CO_2 + Ethanol
Normal Blood Level	70–110 mg/dL (Fasting)

4.2 Fructose (Fruit Sugar / Laevulose)

Formula: $C_6H_{12}O_6$ (Ketohexose) — सबसे मीठी Natural Sugar। Furanose Ring (5-membered)।

- ➤ Optical Rotation: **Laevorotatory (-92.4°)** → इसलिए Laevulose कहते हैं।
- ➤ Sucrose Hydrolysis → Glucose + Fructose = **Invert Sugar** (Laevorotatory)।

➤ Metabolism: Liver में Fructose → Fructose-1-Phosphate → Glycolysis में प्रवेश।

4.3 Galactose

Formula: $C_6H_{12}O_6$ (Aldohexose) — Glucose का **C4 Epimer**। Lactose (Milk Sugar) का घटक।

➤ Liver में: Galactose → Glucose-1-Phosphate (Galactose-1-P Uridyl Transferase enzyme द्वारा)

➤ इस enzyme की कमी → **Galactosemia** रोग।

5. Disaccharides — संरचना

Disaccharide	घटक Units	Bond	Reducing?	स्रोत
Sucrose (Table Sugar)	α-Glucose + β-Fructose	α1→β2	Non-Reducing ✗	Sugarcane, Beetroot
Maltose (Malt Sugar)	α-Glucose + α-Glucose	α1→4	Reducing ✓	Starch Hydrolysis
Lactose (Milk Sugar)	β-Galactose + α-Glucose	β1→4	Reducing ✓	दूध — 4.5%

की कमी → Bloating, Diarrhea, Gas।

6. Polysaccharides — रासायनिक प्रकृति

6.1 Starch (मण्ड)

➤ Amylose (20–25%): Unbranched, α1→4 bonds — I_2 Test: **Blue-black** रंग।

➤ Amylopectin (75–80%): Branched — α1→4 + α1→6 bonds, हर 24–30 glucose पर branch।

➤ स्रोत: चावल, गेहूँ, आलू, मक्का।

6.2 Glycogen (Animal Starch)

- जानवरों में Glucose का भंडारण रूप — **Liver (~100g)** और **Muscle (~400g)**।
- Amylopectin से अधिक Branched — हर 8–12 glucose पर branch। I_2 Test: **Reddish-brown**
- Blood Glucose ↓ → Glycogen → Glucose (Glycogenolysis by Glucagon)।

6.3 Cellulose

- **β-1→4 Glycosidic Bonds** — Unbranched, Linear। मनुष्य नहीं पचा सकते।
- पौधों की Cell Wall का मुख्य घटक। Dietary Fiber → Bowel movement में सहायक।

गुण	Starch	Glycogen	Cellulose
स्रोत	पौधे	जानवर (Liver, Muscle)	Plant Cell Wall
Bond	α1→4, α1→6	α1→4, α1→6	β1→4
Branching	Moderate	Highly Branched	None (Linear)
Iodine Test	Blue-black	Reddish-brown	कोई नहीं
मनुष्य में पाचन	हाँ	हाँ	नहीं

7. गुणात्मक परीक्षाएँ (Qualitative Tests for Carbohydrates)

परीक्षण	Reagent	परिणाम	क्या पहचानता है
Molisch's Test	α-Naphthol + Conc. H_2SO_4	Purple ring at junction	सभी Carbohydrates (General)
Benedict's Test	$CuSO_4$ + Na Citrate + Na_2CO_3	Red/Orange precipitate	Reducing Sugars
Fehling's Test	Fehling A + Fehling B	Brick-red precipitate	Reducing Sugars
Seliwanoff's Test	Resorcinol + Conc. HCl	Cherry Red color	Ketoses (Fructose)
Bial's Test	Orcinol + $FeCl_3$	Blue-green color	Pentoses (Ribose)

Iodine Test	I_2 / KI solution	Blue-black = Starch	Starch
Osazone Test	Phenylhydrazine + Heat	Yellow crystals	Aldoses एवं Ketoses
Barfoed's Test	Cu Acetate + Acetic Acid	Red precipitate (fast)	Monosaccharides vs Disaccharides

8. जैविक भूमिका (Biological Role of Carbohydrates)

- ➤ **ऊर्जा उत्पादन:** Glucose Glycolysis → TCA Cycle → **38 ATP/molecule**
- ➤ **ऊर्जा भंडारण:** Glycogen (Liver + Muscle) = ~500g Glucose reserve
- ➤ **संरचना:** Cellulose — Plant Cell Wall; Chitin — Fungi/Arthropod exoskeleton
- ➤ **Glycoproteins/Glycolipids:** Cell recognition, ABO Blood Group markers
- ➤ **Nucleic Acids:** Ribose (RNA) और Deoxyribose (DNA) — Pentose sugars
- ➤ **Detoxification:** Liver में Glucuronic Acid toxic substances को Conjugate करती है
- ➤ **Dietary Fiber:** Cellulose — Bowel movement; Cholesterol absorption कम करता है

9. Blood Glucose Regulation

Hormone	Effect on Blood Glucose	स्रावित कहाँ से
Insulin	Blood Glucose ↓ — Glucose uptake ↑	Pancreas — Beta (β) Cells
Glucagon	Blood Glucose ↑ — Glycogenolysis ↑	Pancreas — Alpha (α) Cells
Cortisol	Gluconeogenesis ↑	Adrenal Cortex
Epinephrine	Glycogenolysis — Emergency Glucose release	Adrenal Medulla

10. Carbohydrate से संबंधित रोग

रोग	कारण	लक्षण
Diabetes Mellitus Type 1	Insulin उत्पादन नहीं — Beta cells autoimmune destruction	Hyperglycemia, Polyuria, Polydipsia, Ketoacidosis
Diabetes Mellitus Type 2	Insulin Resistance — Peripheral cells respond नहीं	Hyperglycemia, Obesity, Fatigue
Hypoglycemia	Blood Glucose < 70 mg/dL	Weakness, Sweating, Tremors, Coma
Galactosemia	Galactose-1-P Uridyl Transferase enzyme की कमी	Jaundice, Liver damage, Mental retardation
Glycogen Storage Disease	Glycogen metabolism enzymes की कमी (Von Gierke's)	Hepatomegaly, Hypoglycemia
Lactose Intolerance	Lactase enzyme की कमी	Bloating, Diarrhea, Gas

☆ Booster Points (D.Pharmacy Competitive Exam)
❖ Carbohydrates का सामान्य सूत्र = $C_n(H_2O)_n$ — इन्हें Saccharides भी कहते हैं।
❖ Glucose = Blood Sugar (Dextrose) — Normal Fasting Level = 70–110 mg/dL।
❖ Sucrose = α-Glucose + β-Fructose (α1→β2 bond) — एकमात्र Non-Reducing Disaccharide।
❖ Lactose = β-Galactose + α-Glucose (β1→4 bond) — Milk Sugar (4.5% in milk)।
❖ Maltose = α-Glucose + α-Glucose (α1→4 bond) — Reducing Sugar।
❖ Starch: Amylose (Unbranched) + Amylopectin (Branched, α1→4 + α1→6)।
❖ Iodine Test: Starch = Blue-black; Glycogen = Reddish-brown।
❖ Seliwanoff's Test: Cherry Red → Ketoses (Fructose) की पहचान।
❖ Molisch's Test: Purple Ring → सभी Carbohydrates — General Test।
❖ Glycogen = Animal Starch — Liver + Muscle में, Highly Branched (हर 8–12 glucose पर)।
❖ Cellulose में β-1→4 bond — मनुष्य पचा नहीं सकते (Cellulase enzyme absent)।
❖ Fructose = Sweetest Natural Sugar; Laevorotatory (-92.4°)।
❖ Galactose = Glucose का C4 Epimer; Galactosemia — enzyme की कमी।
❖ Insulin — Pancreas Beta (β) Cells; Glucagon — Pancreas Alpha (α) Cells।
❖ Carbohydrates: 4 kcal/g; Proteins: 4 kcal/g; Fats: 9 kcal/g।

Topic 3: प्रोटीन (Proteins)

1. परिभाषा (Definition)

Proteins (प्रोटीन) वे जटिल जैव-अणु हैं जो **Amino Acids** से मिलकर बने होते हैं और **Peptide Bonds** से जुड़े होते हैं। इनमें C, H, O, N और S तत्व होते हैं।

Protein शब्द Greek शब्द **'Proteios'** से आया है — जिसका अर्थ है 'Primary' या 'First Rank'। यह जीवन के लिए अत्यंत आवश्यक हैं।

Proteins के निर्माण खंड (Building Blocks) = **Amino Acids** (20 प्रकार के Standard Amino Acids)।

2. Proteins का वर्गीकरण (Classification of Proteins)

2.1 संघटन के आधार पर (Based on Composition)

प्रकार	विशेषता	उदाहरण
Simple Proteins	केवल Amino Acids — कोई अन्य घटक नहीं	Albumin, Globulin, Glutelin, Prolamine, Collagen
Conjugated Proteins	Amino Acids + Non-protein (Prosthetic Group)	Glycoprotein (Carb+), Lipoprotein (Lipid+), Nucleoprotein (Nucleic acid+), Haemoprotein (Haem+), Phosphoprotein (Phosphate+), Chromoprotein (pigment+)
Derived Proteins	Proteins के Hydrolysis products	Proteoses, Peptones, Peptides (Primary और Secondary)

2.2 घुलनशीलता के आधार पर (Based on Solubility)

प्रोटीन	घुलनशीलता	उदाहरण
Albumins	जल में घुलनशील; Heat से Coagulate	Serum Albumin, Egg Albumin (Ovalbumin), Lactalbumin
Globulins	जल में अघुलनशील; NaCl solution में घुलनशील	Serum Globulin, Myosin
Glutelins	Dilute Acid/Alkali में घुलनशील	Glutenin (Wheat), Oryzenin (Rice)

Prolamins	70% Alcohol में घुलनशील	Gliadin (Wheat), Zein (Maize)
Histones	Dilute Acid में घुलनशील; Water में भी	DNA से जुड़े — Chromosomes में
Protamines	Strong Alkali में अघुलनशील; सरल Proteins	Sperm Nuclei में — Salmine, Clupeine
Scleroproteins (Albuminoids)	जल और सामान्य Solvents में अघुलनशील	Collagen (हड्डी), Keratin (बाल, नाखून), Elastin (tendons)

3. Amino Acids — परिभाषा एवं वर्गीकरण

3.1 परिभाषा

Amino Acids वे कार्बनिक यौगिक हैं जिनमें कम से कम एक **Amino Group (-NH_2)** और एक **Carboxyl Group (-COOH)** होता है। इनमें एक **R group (Side Chain)** भी होता है जो प्रत्येक amino acid को unique बनाता है।

General Formula: **NH_2 — CHR — COOH**

Standard Amino Acids: **20** प्रकार (सभी L-configuration में)।

3.2 रासायनिक प्रकृति के आधार पर वर्गीकरण (Based on Chemical Nature of R group)

वर्ग	R Group का गुण	उदाहरण
Aliphatic (Non-polar)	Hydrophobic — Non-polar R group	Glycine, Alanine, Valine, Leucine, Isoleucine, Proline
Aromatic	Benzene Ring — Hydrophobic	Phenylalanine, Tyrosine, Tryptophan
Sulphur-containing	Thiol (-SH) या Thioether group	Cysteine (-SH), Methionine (-S-CH_3)
Alcoholic	Hydroxyl (-OH) group	Serine, Threonine, Tyrosine

Acidic (Negatively charged)	Extra -COOH group — Negative charge	Aspartic Acid (Asp), Glutamic Acid (Glu)
Basic (Positively charged)	Extra -NH_2 या Guanidinium group	Lysine, Arginine, Histidine
Amides	Amide group (-$CONH_2$)	Asparagine, Glutamine

3.3 पोषण संबंधी आवश्यकता के आधार पर (Nutritional Classification)

वर्ग	विशेषता	उदाहरण
Essential Amino Acids (अनिवार्य)	शरीर स्वयं नहीं बना सकता — आहार से लेना आवश्यक	PVT TIM HALL: Phenylalanine, Valine, Threonine, Tryptophan, Isoleucine, Methionine, Histidine, Arginine, Leucine, Lysine
Non-Essential Amino Acids (अनावश्यक)	शरीर स्वयं संश्लेषित कर सकता है	Glycine, Alanine, Serine, Cysteine, Tyrosine, Aspartate, Glutamate, Asparagine, Glutamine, Proline
Semi-Essential (Conditionally Essential)	सामान्यतः body बनाती है, लेकिन बीमारी/बचपन में आहार से जरूरी	Arginine (growth में), Histidine (infants में)

याद करने का Trick: **PVT TIM HaLL** = Phenylalanine, Valine, Threonine, Tryptophan, Isoleucine, Methionine, Histidine, Leucine, Lysine (+ Arginine = 10 Essential)

4. Proteins की संरचना — चार स्तर (4 Levels of Protein Structure)

4.1 Primary Structure (प्राथमिक संरचना)

Amino Acids का **Linear Sequence (क्रम)** — Peptide Bonds (-CO-NH-) से जुड़ा।

इसे **Sanger's Method** द्वारा determine किया जाता है। यह Protein का Genetic Code निर्धारित करती है।

- Peptide Bond: $-NH_2$ + -COOH → **-CO-NH-** + H_2O (Condensation Reaction)
- 2 AA = Dipeptide; 3 AA = Tripeptide; >10 AA = Polypeptide; >50 AA = Protein

4.2 Secondary Structure (द्वितीयक संरचना)

Polypeptide chain का **Local Folding Pattern** — **Hydrogen Bonds** से स्थिर।

प्रकार	संरचना	उदाहरण
α-Helix	Right-handed spiral; 3.6 AA/turn; H-bonds parallel	Keratin (बाल, नाखून), Myoglobin
β-Pleated Sheet	Parallel या Antiparallel chains; H-bonds perpendicular	Silk Fibroin, β-Keratin
β-Turn	4 Amino Acids में 180° turn	Globular Proteins में
Random Coil	अनियमित संरचना	Disordered regions

4.3 Tertiary Structure (तृतीयक संरचना)

Polypeptide की **3D Folded Shape** — जो Protein को उसकी Biological Activity देती है।

यह निम्न Bonds द्वारा स्थिर होती है:

- **Hydrogen Bonds** — Polar groups के बीच
- **Disulfide Bonds (-S-S-)** — Cysteine residues के बीच (Covalent)
- **Ionic Bonds (Salt Bridges)** — Acidic और Basic groups के बीच
- **Hydrophobic Interactions** — Non-polar R groups आपस में मिलते हैं
- **Van der Waals Forces** — Weak, but contribute

उदाहरण: **Myoglobin** (153 AA; 8 α-helices; Heme group — O_2 binding)

4.4 Quaternary Structure (चतुर्थांश संरचना)

2 या अधिक Polypeptide chains (**Subunits**) का **Combination**। Non-covalent interactions से स्थिर।

उदाहरण: **Hemoglobin** = 2α + 2β subunits (4 polypeptide chains); **Collagen** = Triple helix (3 chains); **Insulin** = 2 chains (A + B chains)।

स्तर	Bond का प्रकार	Feature	उदाहरण
Primary	Peptide Bond (Covalent)	AA Sequence	Insulin
Secondary	H-Bonds	α-Helix, β-Sheet	Keratin, Silk
Tertiary	H-Bond, S-S, Ionic, Hydrophobic	3D Folding	Myoglobin
Quaternary	Non-covalent (mainly)	Multiple Subunits	Hemoglobin

5. Proteins की गुणात्मक परीक्षाएँ (Qualitative Tests)

परीक्षण	Reagent	परिणाम	क्या पहचानता है
Biuret Test	NaOH + $CuSO_4$	Violet/Purple color	Peptide bonds (2+ peptide bonds) — Proteins
Ninhydrin Test	Ninhydrin reagent	Purple/Blue color (Ruhemann's Purple)	Free Amino Acids और Proteins
Xanthoproteic Test	Conc. HNO_3 + Heat → NaOH	Yellow → Orange color	Aromatic AA (Phe, Tyr, Trp)
Million's Test	$Hg(NO_3)_2$ + HNO_3 → $NaNO_2$	Red precipitate	Tyrosine (Phenolic group)
Hopkins-Cole Test	Glyoxylic Acid + Conc. H_2SO_4	Purple ring	Tryptophan
Sakaguchi Test	α-Naphthol + NaOCl	Red color	Arginine (Guanidinium group)

Lead Acetate Test	Lead Acetate + NaOH + Heat	Black precipitate	Sulphur-containing AA (Cys, Met)
Pauly's Test	Diazotized Sulfanilic Acid	Red color	Histidine, Tyrosine

6. Proteins की जैविक भूमिका (Biological Role)

- **Enzymatic:** सभी Enzymes Proteins हैं — Amylase, Lipase, Pepsin, Trypsin।
- **Structural:** Collagen (हड्डी, त्वचा), Keratin (बाल, नाखून), Elastin (Tendons, Ligaments)।
- **Transport:** Hemoglobin (O_2), Albumin (Fatty acids, Drugs), Transferrin (Iron)।
- **Hormonal:** Insulin, Glucagon, Growth Hormone, Prolactin — Protein Hormones।
- **Immune Function:** Antibodies (Immunoglobulins — IgG, IgM, IgA, IgD, IgE) — Proteins।
- **Contraction:** Myosin और Actin — Muscle contraction में।
- **Blood Clotting:** Fibrinogen → Fibrin (Thrombin द्वारा) — Coagulation।
- **Receptor:** Insulin Receptor, Hormone Receptors — Cell surface पर।
- **Storage:** Ferritin (Iron), Ovalbumin (Egg white), Casein (Milk)।

7. Amino Acids की जैविक भूमिका

Amino Acid	विशेष जैविक भूमिका
Glycine	Collagen में प्रचुर; Bile Acids का घटक; पोर्फिरिन synthesis
Tryptophan	Serotonin और Melatonin का पूर्वगामी (Precursor); Niacin (Vit B_3) synthesis
Phenylalanine	Tyrosine का Precursor; Phenylketonuria में Phenylalanine accumulate होता है
Tyrosine	Thyroid Hormones (T_3, T_4), Dopamine, Adrenaline का Precursor

Histidine	Histamine का Precursor (Allergic reactions में)
Arginine	Urea Cycle का घटक; Nitric Oxide (NO) का Precursor
Cysteine	Disulfide Bonds (-S-S-) बनाता है; Glutathione का घटक
Glutamate	Neurotransmitter; GABA का Precursor
Aspartate	Purine/Pyrimidine synthesis में; Urea Cycle में

8. Protein Malnutrition से संबंधित रोग

रोग	कारण	लक्षण
Kwashiorkor	Protein की कमी (Calories पर्याप्त)	Edema, Pot belly, Depigmented hair, Fatty liver, Growth retardation
Marasmus	Protein + Calories दोनों की कमी	Severe wasting, 'Old man face', No Edema, Very thin
Phenylketonuria (PKU)	Phenylalanine Hydroxylase enzyme की कमी → Phenylalanine accumulation	Mental retardation, Seizures, Fair skin, Musty odor
Albinism	Tyrosinase enzyme की कमी → No Melanin production	Skin, Hair, Eye में Pigment नहीं
Alkaptonuria	Homogentisate Oxidase की कमी → Homogentisic Acid accumulation	Urine काला होता है (Ochronosis), Arthritis

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ Proteins = Amino Acids + Peptide Bonds। Protein शब्द = Greek 'Proteios' = First Rank।
❖ Standard Amino Acids = 20 (सभी L-configuration में)।
❖ Essential Amino Acids (10): PVT TIM HALL = Phe, Val, Thr, Trp, Ile, Met, His, Arg, Leu, Lys।
❖ Biuret Test: Violet/Purple → Proteins (Peptide Bonds की पहचान)।
❖ Ninhydrin Test: Purple (Ruhemann's Purple) → Free Amino Acids।
❖ Xanthoproteic Test: Yellow → Orange → Aromatic Amino Acids (Tyr, Phe, Trp)।
❖ Million's Test: Red → Tyrosine (Phenolic OH group)।
❖ Primary Structure: Amino Acid Sequence (Peptide Bond, Covalent)।
❖ Secondary Structure: α-Helix और β-Sheet (Hydrogen Bonds द्वारा stabilize)।
❖ Tertiary Structure: 3D Folding (H-bond + S-S bond + Ionic + Hydrophobic)।
❖ Quaternary Structure: Multiple Subunits — Hemoglobin (2α+2β), Collagen (Triple helix)।
❖ Kwashiorkor = Protein कमी = Edema + Pot belly (Calories पर्याप्त)।
❖ Marasmus = Protein + Calorie दोनों की कमी = Severe Wasting (No Edema)।
❖ Phenylketonuria: Phenylalanine Hydroxylase ↓ → Mental Retardation।
❖ Hemoglobin = 4 Subunits (2α + 2β); प्रत्येक में 1 Heme group = O_2 carrying।

Topic 4: वसा / लिपिड (Lipids)

1. परिभाषा (Definition)

Lipids (लिपिड/वसा) वे जैव-अणु हैं जो **जल में अघुलनशील (Hydrophobic)** और **Organic solvents (Ether, Chloroform, Benzene) में घुलनशील** होते हैं। इनमें C, H और O तत्व होते हैं तथा कुछ में N, P, S भी।

Lipids **9 kcal/gram** ऊर्जा प्रदान करते हैं — Carbohydrates और Proteins से दोगुनी अधिक।

2. वर्गीकरण (Classification of Lipids)

वर्ग	विशेषता	उदाहरण
Simple Lipids (सरल वसा)	Fatty Acids + Alcohol (Glycerol या Higher Alcohol)	Triglycerides (Oils & Fats), Waxes (Beeswax, Carnauba wax)
Compound Lipids (संयुक्त वसा)	Fatty Acids + Alcohol + अन्य Group	Phospholipids (P), Glycolipids (Carbohydrate), Lipoproteins (Protein), Sphingolipids
Derived Lipids (व्युत्पन्न वसा)	Simple/Compound Lipids के Hydrolysis उत्पाद	Fatty Acids, Glycerol, Steroids (Cholesterol), Fat-soluble Vitamins, Ketone bodies

3. Triglycerides की संरचना एवं गुण (Structure & Properties of Triglycerides)

Triglycerides (TG): 1 Glycerol + 3 Fatty Acids → Ester Bonds द्वारा जुड़े। जल का अणु निकलता है (Esterification)।

Glycerol + 3 Fatty Acids → **Triglyceride + $3H_2O$** (Condensation Reaction)

3.1 Fats vs Oils में अंतर

गुण	Fats (ठोस वसा)	Oils (तरल वसा)
Physical State	कमरे के तापमान पर ठोस (Solid)	कमरे के तापमान पर तरल (Liquid)

Fatty Acid Type	Saturated Fatty Acids — अधिक	Unsaturated Fatty Acids — अधिक
Origin	जानवरों से (Animal source)	पौधों से (Plant source)
Melting Point	उच्च (High)	निम्न (Low)
Double Bonds	नहीं या कम	हाँ (1 या अधिक)
उदाहरण	Butter, Ghee, Lard, Tallow	Mustard oil, Sunflower, Olive, Coconut
Health Impact	LDL ↑ — Atherogenic	HDL ↑ (Unsaturated) — Cardioprotective

3.2 Triglycerides के रासायनिक गुण

- **Saponification:** Fats + NaOH → Soap (Sodium Salt of Fatty Acid) + Glycerol। Saponification Value = 1g fat को saponify करने के लिए KOH के mg।
- **Iodine Number:** 100g fat में absorbed Iodine के gram = Unsaturation का माप। Iodine No. ↑ = Unsaturation ↑।
- **Rancidity:** Fats का oxidative deterioration — Hydrolytic Rancidity (Lipase enzyme) या Oxidative Rancidity (O_2 + UV)।
- **Hydrogenation:** Liquid oils + H_2 (Ni catalyst) → Solid fats (Vanaspati Ghee)। Trans fats बनते हैं।
- **Emulsification:** Bile Salts द्वारा Fats को छोटे droplets में — Digestion के लिए।

4. Fatty Acids का वर्गीकरण

4.1 Chemical Nature के आधार पर

प्रकार	Double Bonds	उदाहरण
Saturated (संतृप्त)	कोई Double Bond नहीं	Acetic (C2), Butyric (C4), Palmitic (C16), Stearic (C18), Arachidic (C20)

Monounsaturated (MUFA)	1 Double Bond	Oleic Acid (C18:1, ω-9) — Olive oil में
Polyunsaturated (PUFA)	2+ Double Bonds	Linoleic (C18:2, ω-6), Linolenic (C18:3, ω-3), Arachidonic (C20:4, ω-6)

4.2 Nutritional Requirement के आधार पर

वर्ग	विशेषता	उदाहरण
Essential Fatty Acids (EFA / Vitamin F)	शरीर स्वयं नहीं बना सकता — आहार से जरूरी	Linoleic Acid (ω-6), α-Linolenic Acid (ω-3)
Non-Essential Fatty Acids	शरीर स्वयं संश्लेषित कर सकता है	Palmitic Acid, Stearic Acid, Oleic Acid

EFA की कमी → **Dermatitis**, Growth retardation, Reproductive failure, Poor wound healing।

ω-3 Fatty Acids (EPA, DHA) → **Cardiovascular protection**, Anti-inflammatory — Fish oil में।

5. Cholesterol — संरचना एवं कार्य

Cholesterol एक Steroid (Sterol) है जिसका आण्विक सूत्र **$C_{27}H_{46}O$** है। यह Cyclopentanoperhydrophenanthrene ring पर आधारित है।

- ➤ स्रोत: पशु-उत्पाद — Egg yolk, Dairy, Meat, Organ meats (Liver)। पौधों में Cholesterol नहीं।
- ➤ शरीर में Cholesterol का लगभग **70–80% Liver** स्वयं बनाता है।

5.1 Cholesterol के कार्य (Functions)

कार्य	विस्तार
Cell Membrane Fluidity	Membrane में embed होकर Fluidity और Rigidity balance करता है।
Steroid Hormones का Precursor	Cortisol, Aldosterone, Testosterone, Estrogen, Progesterone — सभी Cholesterol से।

Bile Acids का Precursor	Liver में Cholesterol → Bile Acids (Cholic, Chenodeoxycholic) → Fat digestion।
Vitamin D Synthesis	Skin में UV light द्वारा 7-Dehydrocholesterol → Vitamin D_3।
Nerve Myelin Sheath	Cholesterol Myelin का घटक है — Nerve conduction में सहायक।

Normal Serum Cholesterol: **< 200 mg/dL (Desirable)**; **200–239 = Borderline High**; **> 240 mg/dL = High**

6. Lipoproteins — प्रकार, संघटन एवं कार्य

Lipoproteins Lipid + Protein के Complex हैं जो रक्त में Lipids का परिवहन करते हैं। जल में अघुलनशील Lipids को Protein cover देती है।

Lipoprotein	Density	TG (%)	Cholesterol (%)	कार्य
Chylomicrons	सबसे कम (<0.95)	85–88%	2–7%	Dietary Fats: Intestine → Lymph → Blood
VLDL (Very Low Density)	0.95–1.006	50–65%	15–20%	Liver → Triglycerides को Tissues तक
IDL (Intermediate)	1.006–1.019	31%	31%	VLDL से LDL बनने का मध्यवर्ती
LDL ('Bad' Cholesterol)	1.019–1.063	8–10%	40–50%	Cholesterol → Tissues तक। Atherogenic।
HDL ('Good' Cholesterol)	1.063–1.210 (सबसे अधिक)	5%	16–20%	Reverse Cholesterol Transport — Tissues → Liver। Cardioprotective।

का Apolipoprotein; Apo-A1 = HDL का Apolipoprotein।

7. Phospholipids

Phospholipids: Glycerol + 2 Fatty Acids + Phosphate + Nitrogenous Base। ये Cell Membrane के मुख्य घटक हैं।

Phospholipid	Nitrogenous Base	कार्य
Phosphatidylcholine (Lecithin)	Choline	Cell Membrane; Lung Surfactant; Liver में Fat transport
Phosphatidylethanolamine (Cephalin)	Ethanolamine	Blood Clotting; Brain में अधिक
Phosphatidylserine	Serine	Brain के Neurons में; Apoptosis में role
Phosphatidylinositol	Inositol	Signal Transduction (Second messenger)
Sphingomyelin	Choline (Sphingosine backbone)	Nerve Myelin Sheath — No Glycerol

8. Lipids की गुणात्मक परीक्षाएँ (Qualitative Tests)

परीक्षण	Reagent/Method	परिणाम एवं उपयोग
Sudan III / Sudan IV Test	Sudan III or Sudan IV Stain	Lipids को Orange-Red रंग देता है
Acrolein Test	Glycerol + $KHSO_4$ → Heat	Acrolein की तीखी गंध → Glycerol/Triglycerides की पहचान
Saponification Test	KOH + Alcohol + Heat	Soap बनता है → Esters की पहचान
Iodine Number	I_2 absorption	Unsaturated Fatty Acids की मात्रा

Acid Value	KOH mg/g	Free Fatty Acids — Rancidity का indicator
Liebermann-Burchard Test	Acetic Anhydride + H_2SO_4	Green → Blue → Green → Purple → Sterols (Cholesterol) की पहचान

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ Lipids जल में अघुलनशील (Hydrophobic) और Organic solvents में घुलनशील होते हैं।
❖ Lipids: 9 kcal/gram — Carbohydrates और Proteins से दोगुनी ऊर्जा।
❖ Essential Fatty Acids (EFA) = Linoleic (ω-6) + α-Linolenic (ω-3) — 'Vitamin F' भी कहते हैं।
❖ Triglyceride = 1 Glycerol + 3 Fatty Acids (Ester bonds)।
❖ Saponification Value ↑ = Fatty Acids का MW कम (Short Chain)।
❖ Iodine Number ↑ = Unsaturation ↑ (अधिक Double Bonds)।
❖ Cholesterol का सूत्र: $C_{27}H_{46}O$ — Cyclopentanoperhydrophenanthrene ring।
❖ Cholesterol → Steroid Hormones + Bile Acids + Vitamin D_3 का Precursor।
❖ LDL = 'Bad Cholesterol' (Atherogenic); HDL = 'Good Cholesterol' (Cardioprotective)।
❖ HDL सबसे अधिक Density; Chylomicrons सबसे कम Density।
❖ Lecithin (Phosphatidylcholine) = Lung Surfactant — इसकी कमी → NRDS (Neonatal Respiratory Distress Syndrome)।
❖ Sudan III Test → Lipids Orange-Red रंग।
❖ Liebermann-Burchard Test → Cholesterol (Sterols) की पहचान।
❖ ω-3 Fatty Acids (EPA, DHA) → Fish oil में; Cardiovascular protection।
❖ Hydrogenation: Liquid oils → Solid Fats (Trans Fats बनते हैं — Harmful)।

Topic 5: न्यूक्लिक अम्ल (Nucleic Acids)

1. परिभाषा (Definition)

Nucleic Acids वे Biopolymers हैं जो **Nucleotides** की लंबी श्रृंखलाओं से बने होते हैं। ये **Genetic Information** का भंडारण एवं स्थानांतरण करते हैं।

दो प्रकार: **DNA (Deoxyribonucleic Acid)** — Nucleus में; **RNA (Ribonucleic Acid)** — Nucleus + Cytoplasm दोनों में।

2. Purine एवं Pyrimidine Bases

Nitrogenous Bases — Nitrogen युक्त Ring Compounds — DNA और RNA के घटक।

Base का प्रकार	Base	Ring Structure	DNA/RNA में
Purine (Double Ring — Bicyclic)	Adenine (A)	Imidazole + Pyrimidine	DNA और RNA दोनों में
Purine	Guanine (G)	Imidazole + Pyrimidine	DNA और RNA दोनों में
Pyrimidine (Single Ring — Monocyclic)	Cytosine (C)	Pyrimidine Ring	DNA और RNA दोनों में
Pyrimidine	Thymine (T)	Pyrimidine + Methyl	केवल DNA में
Pyrimidine	Uracil (U)	Pyrimidine Ring	केवल RNA में

Memory Trick: **CUT (Pyrimidines) = C, U, T** — **AG (Purines) = Adenine, Guanine** — 'Pure As Gold'।

3. Nucleosides एवं Nucleotides

3.1 Nucleoside = Nitrogenous Base + Sugar (Glycosidic Bond)

Base	DNA Nucleoside	RNA Nucleoside	Sugar

Adenine	Deoxyadenosine	Adenosine	Deoxyribose / Ribose
Guanine	Deoxyguanosine	Guanosine	Deoxyribose / Ribose
Cytosine	Deoxycytidine	Cytidine	Deoxyribose / Ribose
Thymine	Thymidine	— (नहीं)	Deoxyribose
Uracil	— (नहीं)	Uridine	Ribose

3.2 Nucleotide = Nucleoside + Phosphate Group

Nucleotide में: **Nitrogenous Base + Pentose Sugar + Phosphate Group (1, 2, या 3)**

Nucleotide	Full Name	विशेष कार्य
ATP	Adenosine Triphosphate	ऊर्जा की 'Currency' — 7.3 kcal/mol प्रति phosphate
ADP	Adenosine Diphosphate	ATP ↔ ADP + Pi (Energy transfer)
cAMP	Cyclic AMP	Second Messenger — Hormone signaling
NAD^+ / NADH	Nicotinamide Adenine Dinucleotide	Electron carrier — Metabolism में
FAD / $FADH_2$	Flavin Adenine Dinucleotide	Electron carrier — β-Oxidation, TCA
CoA	Coenzyme A	Acetyl Group carrier — TCA Cycle में
GTP	Guanosine Triphosphate	Protein Synthesis में (Translation)

4. DNA की संरचना — Watson-Crick Model (1953)

Watson और Crick ने 1953 में **X-Ray Crystallography** (Rosalind Franklin के data का उपयोग) के आधार पर DNA का **Double Helix Model** प्रस्तावित किया।

4.1 Double Helix Model की विशेषताएँ

- DNA में **दो polynucleotide chains** होती हैं जो **Anti-parallel** होती हैं (5'→3' और 3'→5')।
- दोनों chains **Hydrogen Bonds** द्वारा जुड़ी हैं — **Complementary Base Pairing**

A — T (2 H-Bonds) | G ≡ C (3 H-Bonds)

- Helix की pitch = **34 Å (3.4 nm)**; प्रति pitch **10 base pairs**; प्रति base pair की दूरी = **3.4 Å**
- Helix का diameter = **20 Å (2 nm)**
- DNA की backbone: Sugar (Deoxyribose) + Phosphate — **Negatively charged**।
- DNA Right-handed helix — **B-DNA** सबसे common physiological form।
- Chargaff's Rule: **A = T; G = C; Purines = Pyrimidines**।

विशेषता	DNA	RNA	अंतर का मुख्य बिंदु
Full Name	Deoxyribonucleic Acid	Ribonucleic Acid	Deoxy vs Ribose
Sugar	Deoxyribose (C2' — H)	Ribose (C2' — OH)	C2' पर OH की उपस्थिति
Bases	A, G, C, T	A, G, C, U	T vs U
Strands	Double Stranded (mostly)	Single Stranded	Strand number
Location	Nucleus (mainly)	Nucleus + Cytoplasm	Location
Function	Genetic Info Store	Protein Synthesis	Role
Stability	अधिक Stable	कम Stable	C2'-OH कारण
Amount	Cell में Fixed	Metabolic state अनुसार Variable	Quantity

5. RNA के प्रकार एवं कार्य (Types of RNA)

RNA प्रकार	Full Name	स्थान	कार्य
mRNA	Messenger RNA	Nucleus → Cytoplasm	DNA का Message Ribosomes तक ले जाता है
tRNA	Transfer RNA	Cytoplasm	Amino Acids को Ribosome तक लाता है; Cloverleaf structure
rRNA	Ribosomal RNA	Ribosomes	Ribosome का structural component — Translation का site
hnRNA	Heterogeneous nuclear RNA	Nucleus	mRNA का precursor (Pre-mRNA)
snRNA	Small nuclear RNA	Nucleus	Splicing में — Spliceosome का घटक
miRNA/siRNA	Micro/Small interfering RNA	Cytoplasm	Gene Silencing — RNAi pathway

6. Replication, Transcription और Translation — संक्षिप्त

प्रक्रिया	क्या होता है	एंजाइम/स्थान
DNA Replication	DNA → DNA (Double Helix copy)	DNA Polymerase — Nucleus; Semi-conservative
Transcription	DNA → mRNA	RNA Polymerase — Nucleus; Template strand पढ़ा जाता है
Translation	mRNA → Protein	Ribosomes (Cytoplasm); tRNA Amino Acids लाती है

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ DNA = Deoxyribose Sugar + Nitrogenous Base + Phosphate। RNA में Ribose Sugar।
❖ Purines (Double ring): Adenine, Guanine। Pyrimidines (Single ring): Cytosine, Uracil, Thymine।
❖ CUT = Pyrimidines (C, U, T); Pure As Gold = AG = Purines।
❖ DNA में Thymine (T); RNA में Uracil (U) — T का स्थान U लेता है।
❖ Watson-Crick Double Helix Model (1953): A=T (2 H-Bonds); G≡C (3 H-Bonds)।
❖ Chargaff's Rule: A=T; G=C; Purines = Pyrimidines।
❖ DNA Helix: Pitch=34Å; 10 bp/turn; Diameter=20Å; Anti-parallel strands।
❖ ATP = Adenosine Triphosphate — Cell की 'Energy Currency' (7.3 kcal/mol)।
❖ cAMP = Second Messenger — Hormonal signaling में।
❖ mRNA = Genetic message; tRNA = Amino Acid transporter; rRNA = Ribosome structural।
❖ tRNA — Cloverleaf Structure; Anticodon loop mRNA के Codon से match करता है।
❖ Replication: DNA→DNA (DNA Polymerase); Transcription: DNA→RNA; Translation: RNA→Protein।
❖ DNA Replication — Semi-Conservative (Meselson-Stahl experiment 1958)।

Topic 6: एंज़ाइम (Enzymes)

1. परिभाषा (Definition)

Enzymes वे जैव-रासायनिक उत्प्रेरक (Biological Catalysts) हैं जो शरीर में होने वाली रासायनिक प्रतिक्रियाओं (Chemical Reactions) की गति बढ़ाते हैं बिना स्वयं नष्ट हुए।

लगभग सभी Enzymes **Proteins** होते हैं (कुछ RNA — Ribozymes भी Enzymatic activity दिखाते हैं)।

Enzymes **Activation Energy** (सक्रियण ऊर्जा) को कम करते हैं। वे **Specific (विशिष्ट)** होते हैं — प्रत्येक Enzyme केवल एक विशेष Substrate पर कार्य करता है।

2. Enzymes के गुण (Properties of Enzymes)

- **Catalytic Efficiency:** एक Enzyme प्रति सेकंड लाखों Substrate molecules को Product में बदल सकता है (Turnover Number)।
- **Specificity (विशिष्टता):** प्रत्येक Enzyme केवल एक Substrate या एक प्रकार के Bond पर कार्य करता है।
- **Protein Nature:** सभी Enzymes Proteins हैं (Ribozymes — RNA Exceptions)।
- **Reversibility:** Enzymes equilibrium को change नहीं करते, बस equilibrium की गति बढ़ाते हैं।
- **Active Site:** Enzyme की Surface पर एक छोटा 3D Region जहाँ Substrate जुड़ता है।
- **Denaturation:** High Temperature, Extreme pH, Heavy metals, UV radiation से Enzyme नष्ट।
- **Cofactors:** Non-protein components (Coenzymes, Metal ions) जो Enzyme activity के लिए जरूरी।

3. IUB एवं MB वर्गीकरण (IUB and MB Classification)

International Union of Biochemistry (IUB) ने Enzymes को 6 Main Classes में बाँटा है।

Class No.	Class Name	Reaction Type	उदाहरण
1. EC 1	Oxidoreductases	Oxidation-Reduction (e^- transfer)	Lactate Dehydrogenase, Alcohol Dehydrogenase, Cytochrome Oxidase
2. EC 2	Transferases	Chemical groups का Transfer	Transaminase (ALT, AST), Hexokinase, Phosphofructokinase

3. EC 3	Hydrolases	Hydrolysis (H_2O से Bond तोड़ना)	Amylase, Lipase, Pepsin, Trypsin, Urease, Acetylcholinesterase
4. EC 4	Lyases	Bond तोड़ना (Non-hydrolytic)	Aldolase, Pyruvate Decarboxylase, Citrate Synthase
5. EC 5	Isomerases	Isomers में Interconversion	Phosphoglucose Isomerase, Triosephosphate Isomerase
6. EC 6	Ligases (Synthetases)	ATP के साथ Bonds जोड़ना	DNA Ligase, Acetyl-CoA Carboxylase, Pyruvate Carboxylase

MB Classification: Enzymes को **Intracellular** (inside cell) और **Extracellular** (secreted outside) में बाँटते हैं।

4. Enzyme Activity को प्रभावित करने वाले कारक

4.1 Temperature (तापमान) का प्रभाव

- तापमान बढ़ने पर Enzyme activity बढ़ती है — **Optimum Temperature: 37°C (शरीर का तापमान)**
- 37°C से अधिक तापमान → Enzyme **Denaturation** → Activity समाप्त।
- Q10 = 2 (10°C वृद्धि पर Reaction rate 2 गुना बढ़ती है)।

4.2 pH का प्रभाव

- प्रत्येक Enzyme का एक Optimum pH होता है:

Enzyme	Optimum pH	स्थान
Pepsin	1.5–2.0	Gastric juice (Stomach)
Trypsin	7.8–8.0	Intestine (Pancreatic juice)
Salivary Amylase	6.8–7.0	Mouth (Saliva)

Urease	7.0	Soil bacteria
Alkaline Phosphatase	8.6–10	Bone, Liver
Acid Phosphatase	5.0	Prostate, RBC

4.3 Substrate Concentration का प्रभाव

- Substrate ↑ → Reaction rate ↑ → Saturation point पर maximum (**Vmax**)।
- **Km (Michaelis Constant):** Substrate Concentration जिस पर Reaction Rate = Vmax/2। Km ↓ = Enzyme-Substrate Affinity ↑।
- Michaelis-Menten Equation: **V = Vmax [S] / (Km + [S])**
- Lineweaver-Burk Double Reciprocal Plot: **1/V vs 1/[S]** — Km और Vmax graphically determine करने के लिए।

4.4 Enzyme Concentration

- Substrate excess में — Enzyme ↑ → Reaction rate ↑ (Linear relationship)।

4.5 Cofactors का प्रभाव

Cofactor का प्रकार	उदाहरण	Enzyme
Metal Ions (Activators)	Mg^{2+}, Zn^{2+}, Fe^{2+}, Cu^{2+}, Ca^{2+}	Hexokinase (Mg^{2+}), Carbonic Anhydrase (Zn^{2+})
Coenzymes	NAD^{+}, FAD, CoA, Pyridoxal Phosphate	Dehydrogenases, Transaminases
Prosthetic Groups	Heme, FAD (tightly bound)	Cytochrome Oxidase (Heme), Succinate Dehydrogenase (FAD)

5. Enzyme की क्रिया-विधि (Mechanism of Action)

5.1 Lock and Key Theory (Fischer, 1894)

Substrate (ताला/Lock) और Enzyme Active Site (चाबी/Key) का आकार बिल्कुल एक-दूसरे में fit होता है — **Rigid, Complementary** संरचना।

5.2 Induced Fit Theory (Koshland, 1958)

Active Site **Flexible** होती है। Substrate के बंधन पर Active Site का आकार बदलता है — **Conformational change** होता है। यह Theory अधिक accepted है।

5.3 Enzyme Catalysis के Steps

- **Step 1:** Enzyme (E) + Substrate (S) → Enzyme-Substrate Complex (ES)
- **Step 2:** ES Complex में Chemical Reaction → Enzyme-Product Complex (EP)
- **Step 3:** EP → Enzyme (E) + Product (P) — Enzyme मुक्त होता है, फिर प्रयोग होता है

$$E + S \rightleftharpoons ES \rightarrow EP \rightleftharpoons E + P$$

6. Enzyme Inhibitors

Enzyme Inhibitors वे पदार्थ हैं जो Enzyme Activity को कम करते हैं।

Inhibition Type	Binding Site	Effect	उदाहरण
Competitive Inhibition	Active Site पर (Substrate से compete)	Km ↑; Vmax same; Excess substrate से दूर होता है	Malonate (Succinate DH inhibitor); Sulfonamides (PABA जैसा)
Non-Competitive Inhibition	Allosteric Site पर (Active Site नहीं)	Km same; Vmax ↓; Excess substrate से दूर नहीं होता	Heavy metals (Hg, Pb, Ag)
Uncompetitive Inhibition	ES Complex पर	Km ↓; Vmax ↓; Both decrease	Lithium (Inositol phosphatase)
Irreversible Inhibition	Covalent bond — Permanent	Enzyme permanently inactivated	Organophosphates (AChE); Aspirin (COX); Penicillin (Transpeptidase)

Allosteric Inhibition	Allosteric site पर Modulator binding	Feedback inhibition — End product inhibits first enzyme	ATP inhibits PFK; CTP inhibits ATCase

7. Therapeutic एवं Pharmaceutical Importance of Enzymes

7.1 Diagnostic Enzymes (Clinical Markers)

Enzyme	ऊंचा स्तर कब	Clinical Significance
ALT (Alanine Transaminase / SGPT)	Hepatitis, Liver damage	Liver Function Test — Most specific for Liver
AST (Aspartate Transaminase / SGOT)	MI (Heart Attack), Liver disease	Liver + Heart disease marker
Alkaline Phosphatase (ALP)	Bone disease, Liver disease, Cholestasis	Bone/Liver pathology
Amylase	Acute Pancreatitis, Mumps	Pancreatic/Salivary gland damage
Lipase	Acute Pancreatitis (Most specific)	Pancreatic damage — More specific than Amylase
CPK / CK	Myocardial Infarction, Muscle disease	CK-MB → Heart; CK-MM → Muscle
LDH (Lactate Dehydrogenase)	MI, Liver disease, Hemolysis	Multiple organs; LDH-1 → Heart
Acid Phosphatase	Prostate Cancer	PSA के साथ Prostate Cancer marker
Cholinesterase	Organophosphate poisoning (↓)	Nerve gas, Pesticide poisoning
GGT (Gamma-Glutamyl Transferase)	Alcoholism, Liver disease, Drug toxicity	Most sensitive Liver enzyme

7.2 Therapeutic उपयोग

Enzyme	स्रोत	Therapeutic Use
Streptokinase / Urokinase	Bacteria / Urine	Thrombolysis — Myocardial Infarction, Pulmonary Embolism में Blood Clot तोड़ता है
Hyaluronidase	Testicular extract	Spreading factor — Drug absorption बढ़ाता है; S.C. injection में
L-Asparaginase	Bacteria (E. coli)	Leukemia treatment — Cancer cells की Asparagine destroy करता है
Trypsin / Chymotrypsin	Pancreatic extract	Anti-inflammatory — Wounds, Edema, Surgery में
Lysozyme	Egg white, Tears	Antibacterial — Eye drops, Throat preparations
DNase (Dornase alfa)	Recombinant	Cystic Fibrosis — Lung secretions पतला करता है
Papain	Papaya	Meat tenderizer; Wound debridement; Digestive enzyme
Collagenase	Bacteria	Wound healing, Burns treatment

7.3 Enzymes as Drug Targets

- **ACE Inhibitors** (Enalapril, Lisinopril) → Angiotensin Converting Enzyme inhibit → BP ↓।
- **HMG-CoA Reductase Inhibitors** (Statins — Atorvastatin) → Cholesterol synthesis ↓।
- **COX-2 Inhibitors** (NSAIDs — Aspirin, Ibuprofen) → Prostaglandin synthesis ↓ → Anti-inflammatory।
- **HIV Protease Inhibitors** (Ritonavir, Saquinavir) → HIV replication ↓।

➤ **Proton Pump Inhibitors** (Omeprazole) → H^+/K^+ ATPase inhibit → Acid ↓।

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ Enzymes = Biological Catalysts (Proteins)। Activation Energy कम करते हैं।
❖ IUB Classification: 6 Classes — Oxidoreductases, Transferases, Hydrolases, Lyases, Isomerases, Ligases।
❖ Lock & Key (Fischer 1894): Rigid fit। Induced Fit (Koshland 1958): Flexible Active Site — More accepted।
❖ Km = Michaelis Constant = Vmax/2 पर Substrate Concentration। Km ↓ = Affinity ↑।
❖ Competitive Inhibition: Km ↑, Vmax same — Excess substrate overcome करता है।
❖ Non-competitive: Km same, Vmax ↓ — Excess substrate overcome नहीं।
❖ Irreversible Inhibition: Covalent bond — Organophosphates (AChE)।
❖ ALT (SGPT) = Liver का Most Specific Enzyme (Hepatitis, Liver damage में ↑)।
❖ Lipase = Acute Pancreatitis का Most Specific Enzyme।
❖ CK-MB ↑ = Myocardial Infarction (Heart Attack)।
❖ Streptokinase → Thrombolytic Agent — MI में Blood Clot तोड़ता है।
❖ L-Asparaginase → Leukemia Treatment (Enzyme Therapy)।
❖ Statins (HMG-CoA Reductase Inhibitors) → Cholesterol ↓।
❖ Optimum Temperature = 37°C; Optimum pH varies (Pepsin=1.5–2.0; Trypsin=7.8–8.0)।
❖ Allosteric Inhibition = Feedback inhibition — End product inhibits first enzyme।

Topic 7: विटामिन (Vitamins)

1. परिभाषा (Definition)

Vitamins (विटामिन) वे कार्बनिक यौगिक हैं जो शरीर की सामान्य वृद्धि, रखरखाव और कार्यों के लिए **अल्प मात्रा में** आवश्यक होते हैं। शरीर इन्हें स्वयं नहीं बना सकता (या पर्याप्त मात्रा में नहीं) — इसलिए ये **आहार से** लेने जरूरी हैं।

Vitamin शब्द **Casimir Funk (1912)** ने दिया — 'Vital Amines' से। (हालांकि सभी Vitamins Amines नहीं होते।)

2. वर्गीकरण (Classification of Vitamins)

वर्ग	Fat-Soluble Vitamins	Water-Soluble Vitamins
Vitamins	A, D, E, K	B-Complex (B1,B2,B3,B5,B6,B7,B9,B12) और Vitamin C
Solubility	Fats और Organic Solvents में	जल (Water) में
Storage	Adipose Tissue और Liver में — Stored होते हैं	Store नहीं होते — Excess urine में निकलता है
Toxicity	Hypervitaminosis संभव (Accumulate होते हैं)	Toxicity कम (Exception: B6 excess = Neuropathy)
Coenzyme Form	Generally No (Vit K = Carboxylase cofactor)	हाँ — अधिकांश B vitamins Coenzymes बनाते हैं

3. Fat-Soluble Vitamins — विस्तृत अध्ययन

3.1 Vitamin A (Retinol)

पहलू	Vitamin A (Retinol)

Chemical Nature	Retinol (Alcohol form), Retinal (Aldehyde), Retinoic Acid; Provitamin = β-Carotene
स्रोत	Animal: Liver, Egg Yolk, Milk, Butter, Fish Liver Oil; Plant: β-Carotene — Carrot, Papaya, Mango, Spinach
RDA	750–900 µg RAE/day (Adult); 350 µg (Children)
Coenzyme Form	Retinal — Visual cycle में; Retinoic Acid — Gene Expression में
कार्य	Vision (Rod cells में Rhodopsin), Epithelial integrity, Bone growth, Immune function, Antioxidant (β-Carotene)
कमी के रोग	Night Blindness (Nyctalopia), Xerophthalmia, Keratomalacia, Bitot's Spots, Dry skin (Hyperkeratosis)
Excess (Toxicity)	Hypervitaminosis A: Liver damage, Headache, Bone pain, Teratogenic (pregnancy में dangerous)

3.2 Vitamin D (Calciferol / Sunshine Vitamin)

पहलू	Vitamin D (Calciferol)
Chemical Nature	Vitamin D_2 (Ergocalciferol — Plant); Vitamin D_3 (Cholecalciferol — Animal/Skin)
Synthesis	Skin में UV Light (Sunlight) → 7-Dehydrocholesterol → Vitamin D_3 → Liver (25-OH-D_3) → Kidney (1,25-OH_2D_3=Calcitriol — Active form)
स्रोत	Sunlight, Fish Liver Oil, Egg Yolk, Fortified Milk; Skin में synthesis
RDA	600–800 IU/day (15–20 µg/day)
Active Form	1,25-Dihydroxycholecalciferol (Calcitriol) — Kidney में बनता है
कार्य	Ca^{2+} और Phosphate absorption (Intestine); Bone mineralization; Muscle function; Immune function
कमी के रोग	Rickets (बच्चों में — Bowing of legs), Osteomalacia (वयस्कों में), Osteoporosis, Hypocalcemia

Toxicity	Hypervitaminosis D: Hypercalcemia, Kidney stones, Soft tissue calcification

3.3 Vitamin E (Tocopherol / Antioxidant Vitamin)

पहलू	Vitamin E (Tocopherol)
Chemical Nature	α, β, γ, δ-Tocopherols; α-Tocopherol सबसे Active
स्रोत	Vegetable Oils (Wheat germ, Sunflower), Nuts, Seeds, Green Leafy Vegetables
RDA	15 mg/day (Adult)
कार्य	Antioxidant (Free Radical Scavenger — PUFA oxidation रोकता है), RBC membrane protection, Immune function
कमी के रोग	Hemolytic Anemia (RBC lysis), Infertility (Lab animals), Neurological degeneration, Muscle weakness
Toxicity	कम toxic; High dose — Anti-coagulant effect, Vitamin K antagonism

3.4 Vitamin K (Phylloquinone / Menadione — Clotting Vitamin)

पहलू	Vitamin K
Chemical Nature	K_1 = Phylloquinone (Plant); K_2 = Menaquinone (Bacteria); K_3 = Menadione (Synthetic)
स्रोत	K_1: Green leafy vegetables (Spinach, Cabbage, Broccoli); K_2: Gut bacteria द्वारा synthesis
RDA	90–120 µg/day
कार्य	Blood Clotting Factors (II, VII, IX, X) का γ-Carboxylation → Active form; Bone protein (Osteocalcin) activation

कमी के रोग	Bleeding tendency, Increased PT (Prothrombin Time), Newborns में — VKDB (Hemorrhagic Disease of Newborn)
Antagonist	Warfarin (Anticoagulant) — Vitamin K Antagonist; Antidote = Vitamin K injection

4. Water-Soluble Vitamins — B-Complex Group

Vitamin	Chemical Name	Coenzyme Form	स्रोत	कमी रोग	RDA
B_1	Thiamine	TPP (Thiamine Pyrophosphate)	Whole grains, Legumes, Pork	Beriberi (Dry/Wet), Wernicke's Encephalopathy	1.1–1.2 mg
B_2	Riboflavin	FMN, FAD	Milk, Eggs, Liver, Green veg	Ariboflavinosis: Angular Stomatitis, Cheilosis, Glossitis	1.1–1.3 mg
B_3	Niacin (Nicotinamide)	NAD^+, $NADP^+$	Meat, Fish, Groundnuts; Tryptophan से बनता है	Pellagra (4D's): Dermatitis, Diarrhea, Dementia, Death	14–16 mg NE
B_5	Pantothenic Acid	Coenzyme A (CoA)	Liver, Eggs, Yeast, Avocado	Burning Feet Syndrome (Rare)	5 mg

B_6	Pyridoxine	PLP (Pyridoxal Phosphate)	Meat, Fish, Banana, Potatoes	Peripheral Neuropathy, Sideroblastic Anemia, Dermatitis	1.3–1.7 mg
B_7	Biotin	Biocytin	Egg yolk, Liver, Nuts; Gut bacteria	Biotin deficiency: Dermatitis, Alopecia (Raw egg white — Avidin blocks)	30 µg
B_9	Folic Acid (Folate)	THF (Tetrahydrofolate)	Green leafy veg, Liver, Legumes	Megaloblastic Anemia, Neural Tube Defects (pregnancy में)	400 µg (750 µg pregnant)
B_{12}	Cobalamin (Cyanocobalamin)	Methylcobalamin, Adenosylcobalamin	Meat, Fish, Eggs, Dairy (Plant में नहीं)	Pernicious Anemia, Subacute Combined Degeneration (SCD) of cord	2.4 µg

5. Vitamin C (Ascorbic Acid)

पहलू	Vitamin C (Ascorbic Acid)
Chemical Nature	L-Ascorbic Acid; Water-Soluble; Easily oxidized
स्रोत	Citrus fruits (Lemon, Orange, Amla/Indian Gooseberry), Tomato, Guava, Peppers
RDA	65–90 mg/day (Adult); 120 mg (Smokers को अधिक)

Coenzyme	Cofactor नहीं — Pro-oxidant/Antioxidant के रूप में कार्य
कार्य	Collagen synthesis (Proline/Lysine hydroxylation), Antioxidant, Iron absorption ($Fe^{3+} \rightarrow Fe^{2+}$), Wound healing, Immune function, Carnitine synthesis
कमी रोग	Scurvy: Bleeding gums, Perifollicular hemorrhage, Poor wound healing, Corkscrew hairs, 'Sailor's disease'
Toxicity	High dose — Kidney stones (Oxalate), Diarrhea

6. Vitamins का Coenzyme Summary

Vitamin	Coenzyme Form	Biochemical Reaction
B_1 (Thiamine)	TPP (Thiamine Pyrophosphate)	Pyruvate → Acetyl-CoA (PDH); α-Ketoglutarate → Succinyl-CoA (OGDC); Transketolase (HMP pathway)
B_2 (Riboflavin)	FMN, FAD	Electron carrier — β-Oxidation (FAD), TCA (Succinate DH = $FADH_2$)
B_3 (Niacin)	NAD^+, $NADP^+$	Electron carrier — Glycolysis, TCA, β-Oxidation; NADPH = HMP pathway, Biosynthesis
B_5 (Pantothenic)	Coenzyme A (CoA)	Acetyl-CoA formation; Fatty Acid Synthesis; TCA Cycle
B_6 (Pyridoxine)	PLP (Pyridoxal Phosphate)	Transamination, Decarboxylation, Deamination; Heme synthesis
B_7 (Biotin)	Biocytin	Carboxylation reactions — Pyruvate Carboxylase, Acetyl-CoA Carboxylase
B_9 (Folic Acid)	THF (Tetrahydrofolate)	1-Carbon transfer — Purine synthesis, dTMP synthesis, Methylation

B_{12} (Cobalamin)	Methylcobalamin; Adenosylcobalamin	Methionine synthesis (Homocysteine→Methionine); Methylmalonyl-CoA→Succinyl-CoA

7. महत्वपूर्ण Vitamin-Disease संबंध

रोग	Vitamin	विशेष तथ्य
Night Blindness	Vit A	Rhodopsin (Rod pigment) = Retinal + Opsin; कमी → Rhodopsin नहीं बनता
Rickets / Osteomalacia	Vit D	बच्चों में Rickets (Bowed legs); वयस्कों में Osteomalacia (Soft bones)
Beriberi	Vit B_1	Dry Beriberi (Neuropathy); Wet Beriberi (Cardiac)
Pellagra	Vit B_3	4D's: Dermatitis, Diarrhea, Dementia, Death; Necklace rash
Scurvy	Vit C	Bleeding gums, Poor wound healing; Collagen synthesis defect
Megaloblastic Anemia	Vit B_9, B_{12}	Large RBC; DNA synthesis defect; Folic acid = Neural tube defect prevention
Pernicious Anemia	Vit B_{12}	Intrinsic Factor (IF) की कमी → B_{12} absorption नहीं → Macrocytic Anemia + Neurological symptoms
Hemolytic Anemia	Vit E	RBC membrane oxidative damage
Bleeding Disorder	Vit K	Clotting factors (II,VII,IX,X) की कमी
Angular Stomatitis	Vit B_2	Mouth के corners पर cracks

☆ Booster Points (D.Pharmacy Competitive Exam)
❖ Fat-Soluble Vitamins: A, D, E, K — Liver और Adipose tissue में stored। Toxicity संभव।
❖ Water-Soluble: B-Complex + Vit C — Stored नहीं; Excess urine में। कम Toxic।
❖ Vitamin A (Retinol) की कमी → Night Blindness (Nyctalopia), Xerophthalmia।
❖ Vitamin D = Sunshine Vitamin; Active form = Calcitriol ($1,25\text{-}(OH)_2D_3$) — Kidney में।
❖ Vitamin D कमी → Rickets (बच्चे), Osteomalacia (वयस्क)।
❖ Vitamin E = Antioxidant Vitamin — PUFA oxidation रोकता है।
❖ Vitamin K = Clotting Vitamin; Warfarin → Vit K antagonist।
❖ Vit B_1 (Thiamine) कमी → Beriberi; Coenzyme = TPP।
❖ Vit B_3 (Niacin) कमी → Pellagra (4D's: Dermatitis, Diarrhea, Dementia, Death)।
❖ Vit B_6 (Pyridoxine) = PLP → Transamination का coenzyme।
❖ Vit B_9 (Folic Acid) कमी → Megaloblastic Anemia + Neural Tube Defects।
❖ Vit B_{12} कमी → Pernicious Anemia + SCD (Subacute Combined Degeneration) — IF जरूरी।
❖ Vit C (Ascorbic Acid) कमी → Scurvy — Bleeding gums, Corkscrew hairs।
❖ Biotin (B_7) — Avidin (Raw egg white) इसे bind करके absorb नहीं होने देता।
❖ Pellagra Corn eaters में — Tryptophan कम होता है; Niacin बनाने के लिए Tryptophan जरूरी।

Topic 8: कार्बोहाइड्रेट का चयापचय (Metabolism of Carbohydrates)

Note: सिलेबस के अनुसार इस Topic में Chemical Structures के बिना केवल Pathways/Cycles का अध्ययन करना है।

1. Glycolysis (ग्लाइकोलाइसिस) — Embden-Meyerhof-Parnas Pathway

1.1 परिचय

Glycolysis वह प्रक्रिया है जिसमें **Glucose** → **Pyruvate** में परिवर्तित होती है। यह **Cytoplasm** में होती है।

- ➤ Oxygen की आवश्यकता: **नहीं** — Anaerobic process (Aerobic conditions में भी होती है)।
- ➤ Net ATP उत्पादन: **2 ATP (Net gain)** per molecule of Glucose।
- ➤ NADH उत्पादन: **2 NADH**

1.2 Glycolysis के 10 Steps — संक्षिप्त

Step	Reaction	Enzyme	ATP/NADH
1	Glucose → Glucose-6-Phosphate	Hexokinase (Glucokinase in Liver)	1 ATP (used)
2	Glucose-6-P → Fructose-6-P	Phosphoglucose Isomerase	—
3	Fructose-6-P → Fructose-1,6-bisP	Phosphofructokinase-1 (PFK-1)	1 ATP (used)
4	Fructose-1,6-bisP → 2 Triose-P	Aldolase	—
5	DHAP → Glyceraldehyde-3-P	Triose Phosphate Isomerase	—
6	G-3-P → 1,3-bisPhosphoglycerate	G-3-P Dehydrogenase	2 NADH
7	1,3-bisPhosphoglycerate → 3-PG	Phosphoglycerate Kinase	2 ATP (Substrate Level)
8	3-Phosphoglycerate → 2-Phosphoglycerate	Phosphoglycerate Mutase	—
9	2-Phosphoglycerate → Phosphoenolpyruvate	Enolase (F^- द्वारा inhibit)	—

10	PEP → Pyruvate	Pyruvate Kinase	2 ATP (Substrate Level)

1.3 Glycolysis — Net Balance

उत्पाद	Aerobic	Anaerobic
ATP (Net)	2 ATP	2 ATP
NADH	2 NADH (→ Mitochondria में 5 ATP)	NADH → Lactate Dehydrogenase → NAD+ regenerate
Pyruvate	2 Pyruvate → TCA Cycle	2 Lactate (Cori Cycle द्वारा Liver → Glucose)

1.4 Regulation of Glycolysis — Key Enzymes

- **Hexokinase:** Glucose-6-Phosphate द्वारा inhibit (product inhibition)। Glucokinase (Liver) — G6P से inhibit नहीं।
- **Phosphofructokinase-1 (PFK-1):** Most important regulatory enzyme। ATP/Citrate → inhibit; AMP/ADP/Fructose-2,6-bisP → activate।
- **Pyruvate Kinase:** ATP/Acetyl-CoA/Alanine → inhibit; Fructose-1,6-bisP → activate।

2. TCA Cycle / Krebs Cycle / Citric Acid Cycle

2.1 परिचय

TCA Cycle **Mitochondria की Matrix** में होती है। यह **Aerobic process** है। Pyruvate → Acetyl-CoA (Pyruvate Dehydrogenase Complex, PDH) → TCA Cycle।

PDH Complex: Pyruvate + CoA + NAD^+ → **Acetyl-CoA + CO_2 + NADH** (Coenzymes: TPP, Lipoamide, FAD, CoA, NAD^+)

2.2 TCA Cycle के 8 Steps

Step	Reaction	Enzyme	Energy

1	Acetyl-CoA + OAA → Citrate (6C)	Citrate Synthase	—
2	Citrate → Isocitrate	Aconitase	—
3	Isocitrate → α-Ketoglutarate + CO_2	Isocitrate Dehydrogenase	1 NADH
4	α-KG → Succinyl-CoA + CO_2	α-Ketoglutarate Dehydrogenase	1 NADH
5	Succinyl-CoA → Succinate	Succinyl-CoA Synthetase	1 GTP
6	Succinate → Fumarate	Succinate Dehydrogenase	1 $FADH_2$
7	Fumarate → Malate	Fumarase	—
8	Malate → Oxaloacetate (OAA)	Malate Dehydrogenase	1 NADH

2.3 TCA Cycle — Net Yield per Acetyl-CoA

उत्पाद	मात्रा
NADH	3 NADH (Steps 3, 4, 8)
$FADH_2$	1 $FADH_2$ (Step 6 — Succinate Dehydrogenase)
GTP	1 GTP = 1 ATP (Step 5)
CO_2	2 CO_2
ATP (via ETC)	10 ATP (3 NADH × 2.5 + 1 $FADH_2$ × 1.5 + 1 GTP)

3. Glycogen Metabolism — संग्रहण एवं विमोचन

3.1 Glycogenesis (Glycogen Synthesis)

➤ स्थान: Liver (100g) और Muscle (400g) — Cytoplasm में।

- Glucose → Glucose-6-P (Hexokinase) → Glucose-1-P (Phosphoglucomutase) → UDP-Glucose (UDP-Glucose Pyrophosphorylase) → Glycogen।
- **Key Enzyme: Glycogen Synthase** — α1→4 bonds बनाता है। Branching Enzyme → α1→6 bonds।
- Insulin → Glycogen Synthase activate → Glycogenesis ↑।

3.2 Glycogenolysis (Glycogen Breakdown)

- Glycogen → Glucose-1-P (Glycogen Phosphorylase) → Glucose-6-P → Glucose।
- **Key Enzyme: Glycogen Phosphorylase** (PLP = Vit B_6 as cofactor) + Debranching Enzyme।
- Glucagon/Epinephrine → Phosphorylase activate (cAMP → PKA → Phosphorylase Kinase → Phosphorylase)।

4. Blood Glucose Level का नियमन

Condition	Mechanism	Hormone
Post-meal (Hyperglycemia)	Glycolysis ↑, Glycogenesis ↑, Lipogenesis ↑	Insulin ↑
Fasting (Hypoglycemia)	Glycogenolysis ↑, Gluconeogenesis ↑	Glucagon ↑, Epinephrine ↑
Stress	Glycogenolysis ↑ (Emergency)	Epinephrine ↑
Normal Fasting	70–110 mg/dL	Balanced
Post-prandial	< 140 mg/dL (2 hrs)	Insulin returns to normal

5. Gluconeogenesis (ग्लूकोनेओजेनेसिस — नये Glucose का निर्माण)

Gluconeogenesis — Non-Carbohydrate precursors से Glucose बनाने की प्रक्रिया — मुख्यतः **Liver** में।

- Precursors: **Pyruvate, Lactate, Glycerol, Amino Acids (Glucogenic)** — Oxaloacetate के माध्यम से।
- यह Glycolysis के reverse नहीं — 3 Bypass steps हैं:
- **Pyruvate → OAA (Pyruvate Carboxylase)** → PEP (PEPCK) — Pyruvate Kinase bypass।
- **Fructose-1,6-bisP → Fructose-6-P (FBPase-1)** — PFK-1 bypass।
- **Glucose-6-P → Glucose (Glucose-6-Phosphatase)** — Hexokinase bypass (Liver में, Muscle में नहीं)।
- Cori Cycle: Muscle Lactate → Liver → Glucose → Muscle में वापस।

6. Carbohydrate Metabolism से संबंधित रोग

रोग	कारण	विशेषता
Diabetes Mellitus Type 1	Insulin absence — Beta cells autoimmune	Hyperglycemia, Ketoacidosis, Polyuria
Diabetes Mellitus Type 2	Insulin Resistance	Obesity, Hyperglycemia, Gradual onset
Hypoglycemia	Blood Glucose < 70 mg/dL — Insulin excess	Weakness, Sweating, Tremors, Coma
Galactosemia	Galactose-1-P Uridyl Transferase ↓	Liver failure, Cataract, Mental retardation
Fructosuria	Fructokinase ↓	Benign — Fructose in urine
Von Gierke's Disease (GSD Type 1)	Glucose-6-Phosphatase ↓	Hepatomegaly, Severe Hypoglycemia
Pompe's Disease (GSD Type 2)	Lysosomal α-Glucosidase ↓	Cardiomegaly, Muscle weakness
McArdle's Disease (GSD Type 5)	Muscle Glycogen Phosphorylase ↓	Muscle cramps, Exercise intolerance

☆ Booster Points (D.Pharmacy Competitive Exam)
❖ Glycolysis: Glucose → 2 Pyruvate; Cytoplasm में; Net = 2 ATP + 2 NADH।
❖ Glycolysis के 3 Key Enzymes: Hexokinase, PFK-1 (Most important), Pyruvate Kinase।
❖ PFK-1 = Most important regulatory enzyme of Glycolysis।
❖ TCA Cycle: Mitochondria Matrix में; Aerobic; 1 Acetyl-CoA → 10 ATP।
❖ TCA Key Enzymes: Isocitrate DH, α-KG DH, Succinyl-CoA Synthetase, Succinate DH, Malate DH।
❖ Pyruvate Dehydrogenase (PDH): Pyruvate → Acetyl-CoA; Coenzymes: TPP, FAD, CoA, NAD^+, Lipoamide।
❖ Total ATP from 1 Glucose (Aerobic): 30–32 ATP।
❖ Glycogenesis Key Enzyme: Glycogen Synthase; Glycogenolysis: Glycogen Phosphorylase।
❖ Insulin → Glycogenesis ↑, Glycolysis ↑। Glucagon → Glycogenolysis ↑, Gluconeogenesis ↑।
❖ Gluconeogenesis: Non-Carb → Glucose; Liver में; 3 unique enzymes (Bypass enzymes)।
❖ Glucose-6-Phosphatase: Liver में present — इसलिए Liver blood glucose release कर सकता है।
❖ Cori Cycle: Lactate (Muscle) → Liver → Glucose → back to Muscle।
❖ Von Gierke's Disease: Glucose-6-Phosphatase ↓ → Hepatomegaly + Severe Hypoglycemia।
❖ Diabetes mellitus: Fasting Glucose > 126 mg/dL; or Post-prandial > 200 mg/dL।

Topic 9: लिपिड का चयापचय (Metabolism of Lipids)

1. परिचय (Introduction)

Lipid Metabolism में तीन प्रमुख प्रक्रियाएँ हैं — **Lipolysis** (वसा का विघटन), **β-Oxidation** (Fatty Acid का ऑक्सीकरण) और **Ketogenesis/Ketolysis** (Ketone Bodies का निर्माण एवं उपयोग)।

2. Lipolysis (लिपोलाइसिस — Triglycerides का विघटन)

2.1 परिभाषा

Lipolysis वह प्रक्रिया है जिसमें Adipose Tissue में संग्रहीत **Triglycerides** → **Glycerol + 3 Fatty Acids** में टूटते हैं। इसे **Mobilization of Fats** भी कहते हैं।

2.2 Lipolysis की प्रक्रिया

- **Step 1:** Triglyceride → Diglyceride + Fatty Acid (**Hormone Sensitive Lipase — HSL**) — Rate-limiting step
- **Step 2:** Diglyceride → Monoglyceride + Fatty Acid (Diglyceride Lipase)
- **Step 3:** Monoglyceride → Glycerol + Fatty Acid (Monoglyceride Lipase)

Products: **Glycerol** → Liver में → Gluconeogenesis; **Fatty Acids** → Blood में Albumin से bound → β-Oxidation के लिए।

2.3 Lipolysis का Regulation

Activators (Lipolysis ↑)	Inhibitors (Lipolysis ↓)	Mechanism
Glucagon	Insulin	cAMP → PKA → HSL Phosphorylation (Active)
Epinephrine/Norepinephrine	Prostaglandins	β-adrenergic receptor → Adenylyl Cyclase ↑
ACTH, Cortisol, GH	Nicotinic Acid (Niacin)	Lipolysis ↓ → TG ↓ → VLDL ↓
Thyroid Hormones	Adenosine	Antilipolytic effect

3. β-Oxidation of Fatty Acids (बीटा-ऑक्सीकरण)

3.1 परिभाषा एवं स्थान

β-Oxidation वह प्रक्रिया है जिसमें Fatty Acids टूटकर **Acetyl-CoA** के रूप में ऊर्जा देते हैं। यह प्रक्रिया **Mitochondrial Matrix** में होती है।

Entry: Fatty Acid + CoA → **Acyl-CoA** (Fatty Acyl-CoA Synthetase, ATP उपयोग होता है) → Mitochondria में **Carnitine Shuttle** द्वारा transport।

3.2 Carnitine Shuttle (Carnitine Transport System)

- Long-chain Fatty Acids Mitochondrial Inner Membrane से नहीं गुजर सकतीं — **Carnitine** की जरूरत।
- Acyl-CoA + Carnitine → Acylcarnitine (**Carnitine Acyltransferase I — CAT-I / CPT-I**) → Inner Membrane cross।
- अंदर: Acylcarnitine → Acyl-CoA + Carnitine (CPT-II)।
- Malonyl-CoA → CPT-I को inhibit करता है → Fatty Acid oxidation ↓ जब Biosynthesis हो रही हो।

3.3 β-Oxidation के चार Steps (प्रत्येक cycle में)

Step	Reaction	Enzyme	Energy
1	Acyl-CoA → Trans-Δ^2-Enoyl-CoA (Dehydrogenation)	Acyl-CoA Dehydrogenase	1 $FADH_2$
2	Trans-Enoyl-CoA + H_2O → L-Hydroxyacyl-CoA (Hydration)	Enoyl-CoA Hydratase	—
3	L-Hydroxyacyl-CoA → Ketoacyl-CoA (Dehydrogenation)	L-Hydroxyacyl-CoA Dehydrogenase	1 NADH
4	Ketoacyl-CoA + CoA → Acetyl-CoA + Shorter Acyl-CoA (Thiolysis)	Thiolase (β-Ketothiolase)	1 Acetyl-CoA

प्रत्येक cycle में Chain 2 Carbons छोटी होती है। यह cycle तब तक चलती है जब तक पूरी Chain टूट न जाए।

3.4 Palmitic Acid (C16) का β-Oxidation — ATP Calculation

घटक	ATP
Cycles of β-Oxidation	7 cycles (C16 → 8 Acetyl-CoA)
$FADH_2$ (7 × 1.5 ATP)	10.5 ATP
NADH (7 × 2.5 ATP)	17.5 ATP
Acetyl-CoA (8 × 10 ATP from TCA)	80 ATP
Activation cost (ATP used)	−2 ATP (Acyl-CoA Synthetase → AMP + PPi)
Net Total	106 ATP

4. Ketogenesis (कीटोनेसिस — Ketone Bodies का निर्माण)

4.1 परिभाषा

Ketogenesis — Acetyl-CoA से **Ketone Bodies** बनने की प्रक्रिया। यह **Liver Mitochondria** में होती है।

Ketone Bodies तीन प्रकार की होती हैं:

- **Acetoacetate** (Primary Ketone Body)
- **β-Hydroxybutyrate / 3-Hydroxybutyrate** (सबसे अधिक मात्रा में)
- **Acetone** (Spontaneous Decarboxylation से — Breath में फल जैसी गंध)

4.2 Ketogenesis के Steps

- **Step 1:** 2 Acetyl-CoA → Acetoacetyl-CoA (Thiolase)
- **Step 2:** Acetoacetyl-CoA + Acetyl-CoA → HMG-CoA (HMG-CoA Synthase) — Rate-limiting step
- **Step 3:** HMG-CoA → Acetoacetate + Acetyl-CoA (HMG-CoA Lyase)
- **Step 4:** Acetoacetate → β-Hydroxybutyrate (β-Hydroxybutyrate Dehydrogenase) या → Acetone (Non-enzymatic)

4.3 Ketogenesis की Conditions

Condition	कारण
Starvation / Fasting	Glucose ↓ → Insulin ↓ → Lipolysis ↑ → Acetyl-CoA ↑ → Ketogenesis ↑
Diabetes Mellitus (Type 1)	Insulin absent → Lipolysis uncontrolled → Acetyl-CoA flood → Ketoacidosis
High Fat / Low Carb Diet	OAA ↓ (Gluconeogenesis में use) → TCA blocked → Acetyl-CoA → Ketones
Alcoholism	Alcohol → NADH ↑ → OAA ↓ → Ketogenesis ↑

5. Ketolysis (कीटोलाइसिस — Ketone Bodies का उपयोग)

Ketolysis — Extra-hepatic Tissues (Brain, Heart, Muscle, Kidney) में Ketone Bodies का **Oxidation** करके **Acetyl-CoA → TCA Cycle → ATP**

- **Step 1:** β-Hydroxybutyrate → Acetoacetate (β-Hydroxybutyrate DH)
- **Step 2:** Acetoacetate + Succinyl-CoA → Acetoacetyl-CoA + Succinate (**Succinyl-CoA Transferase — absent in Liver**)
- **Step 3:** Acetoacetyl-CoA → 2 Acetyl-CoA (Thiolase) → TCA Cycle

Note: Liver Ketone Bodies बनाता है लेकिन खुद use नहीं कर सकता (Succinyl-CoA Transferase absent in Liver)।

6. Lipid Metabolism से संबंधित रोग

रोग	कारण	विशेषता/लक्षण
Diabetic Ketoacidosis (DKA)	Insulin absence (Type 1 DM) → Uncontrolled Ketogenesis	Blood Ketones ↑↑, pH ↓, Fruity breath, Kussmaul breathing, Coma

Fatty Liver (Hepatic Steatosis)	TG accumulation in Liver — Alcohol, Obesity, DM, Starvation	Hepatomegaly, NAFLD → Cirrhosis
Hypercholesterolemia	LDL ↑ → Familial (LDL Receptor defect) या Dietary	Xanthomas, Xanthelasma, Corneal Arcus, Atherosclerosis, CAD risk
Hypertriglyceridemia	TG > 150 mg/dL — Obesity, DM, Alcohol, Hypothyroidism	Pancreatitis risk, Eruptive Xanthomas
Refsum's Disease	Phytanic Acid Oxidase ↓ → Phytanic Acid accumulation	Retinitis Pigmentosa, Cerebellar ataxia, Peripheral neuropathy
Abetalipoproteinemia	Apolipoprotein B48 और B100 की कमी → Chylomicrons + VLDL नहीं बनते	Steatorrhea, Fat-soluble vitamin deficiency, Retinitis

7. Fatty Acid Synthesis (Lipogenesis) — संक्षिप्त

Fatty Acid Synthesis (De Novo) **Cytoplasm** में होती है — Liver, Adipose, Mammary gland में।

- ➤ **Key Enzyme: Acetyl-CoA Carboxylase (ACC)** — Acetyl-CoA → Malonyl-CoA (Rate-limiting, Biotin coenzyme)।
- ➤ **Fatty Acid Synthase (FAS) Complex** — 7 enzymatic activities। NADPH उपयोग।
- ➤ Malonyl-CoA → CPT-I inhibit → β-Oxidation बंद (Synthesis और Oxidation एक साथ नहीं)।
- ➤ Product: Palmitic Acid (C16) primarily।
- ➤ Insulin → ACC activate; Glucagon/Epinephrine → ACC inhibit।

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ Lipolysis: TG → Glycerol + 3 Fatty Acids (Hormone Sensitive Lipase — HSL)।
❖ HSL Activators: Glucagon, Epinephrine; Inhibitors: Insulin, Nicotinic Acid।

- ❖ β-Oxidation: Mitochondrial Matrix में; Carnitine Shuttle द्वारा FA entry।
- ❖ CPT-I (Carnitine Palmitoyltransferase I): β-Oxidation का rate-limiting step।
- ❖ Malonyl-CoA → CPT-I inhibit → FA Synthesis चलते वक्त Oxidation बंद।
- ❖ β-Oxidation के 4 Steps: Dehydrogenation → Hydration → Dehydrogenation → Thiolysis।
- ❖ Palmitic Acid (C16): 7 cycles β-Oxidation → 8 Acetyl-CoA → 106 ATP (Net)।
- ❖ Ketone Bodies: Acetoacetate, β-Hydroxybutyrate, Acetone।
- ❖ Ketogenesis: Liver Mitochondria में; HMG-CoA → Rate-limiting step।
- ❖ Ketolysis: Extra-hepatic Tissues में; Liver खुद use नहीं कर सकता (Succinyl-CoA Transferase absent)।
- ❖ DKA (Diabetic Ketoacidosis): Insulin absent → Uncontrolled Ketogenesis → Fruity breath, Acidosis।
- ❖ Fatty Liver: Liver में TG accumulation — Alcohol, Obesity, DM। NAFLD → Cirrhosis।
- ❖ Familial Hypercholesterolemia: LDL Receptor defect → LDL ↑ → Atherosclerosis, CAD।
- ❖ Fatty Acid Synthesis: Cytoplasm में; Key enzyme = Acetyl-CoA Carboxylase; NADPH use।
- ❖ Starvation: OAA ↓ (Gluconeogenesis में) → TCA blocked → Acetyl-CoA → Ketones।

Topic 10: अमीनो अम्ल का चयापचय (Metabolism of Amino Acids / Proteins)

1. परिचय (Introduction)

Amino Acid Metabolism में मुख्यतः **Transamination**, **Deamination**, **Urea Cycle** और **Decarboxylation** शामिल हैं। Amino Acids के Nitrogen को शरीर से **Urea** के रूप में निकाला जाता है।

2. Transamination (ट्रान्सअमिनेशन)

2.1 परिभाषा

Transamination वह प्रक्रिया है जिसमें एक Amino Acid का **Amino Group (-NH_2)** एक α-Keto Acid पर Transfer होता है। इस प्रक्रिया से नया Amino Acid और नया Keto Acid बनते हैं।

Amino Acid + α-Keto Acid ⇌ New Keto Acid + New Amino Acid (Reversible)

2.2 Enzymes (Transaminases / Aminotransferases)

Enzyme	Reaction	Clinical Importance
ALT (SGPT) Alanine Aminotransferase	Alanine + α-Ketoglutarate ⇌ Pyruvate + Glutamate	Liver disease (Hepatitis) में ↑↑ — Most specific Liver enzyme
AST (SGOT) Aspartate Aminotransferase	Aspartate + α-Ketoglutarate ⇌ OAA + Glutamate	Liver + Heart disease (MI) में ↑ — Less specific

2.3 Coenzyme

PLP (Pyridoxal Phosphate) = Vitamin B_6 का Active Form — सभी Transaminases का Coenzyme। Schiff Base बनाता है।

3. Deamination (डीअमिनेशन)

3.1 Oxidative Deamination

Oxidative Deamination वह प्रक्रिया है जिसमें Amino Acid का **Amino Group (-NH_2)** → **NH_3** के रूप में निकलता है और Keto Acid बनती है।

Glutamate + NAD^+/$NADP^+$ → α-Ketoglutarate + NH_3 + NADH (Glutamate Dehydrogenase, GDH)

- Enzyme: **Glutamate Dehydrogenase (GDH)** — Liver, Kidney, Brain में। Mitochondrial Matrix में।
- ADP/GDP → GDH Activate; ATP/GTP/NADH → GDH Inhibit।

3.2 Non-oxidative Deamination

- **Serine Dehydratase:** Serine → Pyruvate + NH_3

- **Threonine Dehydratase:** Threonine → α-Ketobutyrate + NH_3
- **Histidase:** Histidine → Urocanate + NH_3

4. Urea Cycle (यूरिया चक्र / Ornithine Cycle)

4.1 परिभाषा एवं महत्व

Urea Cycle वह प्रक्रिया है जिसमें Amino Acid Metabolism से उत्पन्न विषाक्त **Ammonia (NH_3)** → **Urea** में परिवर्तित होती है और **Urine** में उत्सर्जित होती है।

- स्थान: **Liver** — Mitochondria + Cytoplasm दोनों में (Bicompartmental)।
- खोजकर्ता: **Hans Krebs और Kurt Henseleit (1932)**
- Urea का सूत्र: **$(NH_2)_2CO$ — 2 Nitrogen, 1 Carbon, 1 Oxygen**
- Normal Blood Urea: **15–40 mg/dL**; Urine Urea: 12–20 g/day।

4.2 Urea Cycle के Steps

Step	Reaction	Enzyme	Location
1	$NH_3 + CO_2 + 2ATP$ → Carbamoyl Phosphate	Carbamoyl Phosphate Synthetase-I (CPS-I)	Mitochondria
2	Carbamoyl Phosphate + Ornithine → Citrulline	Ornithine Transcarbamylase (OTC)	Mitochondria
3	Citrulline + Aspartate + ATP → Argininosuccinate	Argininosuccinate Synthetase	Cytoplasm
4	Argininosuccinate → Arginine + Fumarate	Argininosuccinase (Lyase)	Cytoplasm
5	Arginine + H_2O → Urea + Ornithine	Arginase	Cytoplasm

Ornithine Cycle Carrier: Ornithine Mitochondria → Cytoplasm; Citrulline Cytoplasm → Mitochondria।

Net: **NH_3 + CO_2 + Aspartate → Urea; 3 ATP consumed per Urea।**

4.3 Urea Cycle का Regulation

- **N-Acetylglutamate (NAG):** CPS-I का Allosteric Activator — Rate-limiting step।
- Protein diet ↑ → Urea Cycle Enzyme induction ↑।
- Arginine → NAG Synthase activate → Urea Cycle ↑।

5. Decarboxylation (डिकार्बोक्सिलेशन)

Decarboxylation — Amino Acids से **-COOH Group (CO_2)** निकलकर **Biogenic Amines** बनते हैं।
Enzyme = **Amino Acid Decarboxylase; Coenzyme = PLP (Vit B_6)**।

Amino Acid	Amine Formed	जैविक कार्य
Histidine	Histamine	Allergic reactions, Gastric acid secretion, Inflammation
Tryptophan	Serotonin (5-HT) → Melatonin	Mood regulation, Sleep, Gut motility
Tyrosine	Dopamine → Norepinephrine → Epinephrine	Catecholamines — Neurotransmitters, Stress response
Glutamate	GABA (γ-Aminobutyric Acid)	Inhibitory Neurotransmitter — Brain
Lysine + Methionine	Carnitine	Fatty Acid transport — Carnitine Shuttle
Ornithine	Putrescine → Spermidine → Spermine	Polyamines — Cell proliferation, DNA stabilization
DOPA	Melanin	Skin Pigmentation — Tyrosinase enzyme

6. Ammonia का चयापचय एवं विकार

6.1 Ammonia के स्रोत

- Amino Acid Deamination (मुख्य स्रोत)
- Intestinal Bacteria → Protein/Urea से NH_3 उत्पन्न करती हैं
- Glutamine Hydrolysis → Kidney में
- Purine Nucleotide Catabolism

6.2 Ammonia Toxicity (Hyperammonemia)

Normal Blood Ammonia: 15–45 µg/dL (10–35 µmol/L)

स्थिति	कारण	लक्षण
Hyperammonemia Type I	CPS-I Deficiency	Newborn में Lethargy, Vomiting, Encephalopathy
Hyperammonemia Type II	OTC Deficiency (X-linked)	सबसे common Urea Cycle defect
Liver Failure (Cirrhosis)	Liver में Urea नहीं बन सकती → NH_3 ↑	Hepatic Encephalopathy
Reye's Syndrome	OTC inhibition (Aspirin + Viral infection)	Liver failure, Encephalopathy in children

7. Amino Acid Disorders

रोग	Enzyme Defect	लक्षण
Phenylketonuria (PKU)	Phenylalanine Hydroxylase ↓ (PAH)	Mental retardation, Fair skin, Seizures, Musty (Mouse) odor। Neonatal screening जरूरी।
Tyrosinemia	Fumarylacetoacetate Hydrolase ↓	Liver failure, Renal damage, Peripheral neuropathy
Alkaptonuria	Homogentisate Oxidase ↓	Urine काली (Air में dark), Ochronosis (Joint cartilage black), Arthritis

Albinism	Tyrosinase ↓	Melanin नहीं → Skin/Hair/Eye में Pigment absent; Photosensitivity
Maple Syrup Urine Disease (MSUD)	Branched-chain α-Keto Acid DH ↓	Sweet urine smell, Mental retardation, Leu/Ile/Val accumulate
Homocystinuria	Cystathionine β-Synthase ↓	Homocysteine ↑ → Thrombosis, Lens dislocation, Osteoporosis
Hartnup Disease	Neutral AA transporter defect (Tryptophan absorption ↓)	Pellagra-like rash, Cerebellar ataxia

8. Jaundice (पीलिया) — Bilirubin Metabolism

8.1 Bilirubin का निर्माण

Hemoglobin (Heme) → **Biliverdin** (Heme Oxygenase) → **Bilirubin** (Biliverdin Reductase) → Blood में Albumin से जुड़कर → Liver।

- ➤ Indirect/Unconjugated Bilirubin (Pre-Hepatic): **जल में अघुलनशील, Albumin-bound**
- ➤ Liver में: Bilirubin + Glucuronate (UDP-Glucuronyl Transferase) → **Direct/Conjugated Bilirubin** (जल में घुलनशील)
- ➤ Bile में Excretion → Intestine में Urobilinogen → Stercobilin (मल में) / Urobilin (मूत्र में)

8.2 Jaundice के प्रकार

प्रकार	कारण	Indirect Bili.	Direct Bili.
Pre-hepatic (Hemolytic)	Excess RBC destruction (Hemolysis — Malaria, G6PD)	↑↑ (excess)	Normal
Hepatic (Hepatocellular)	Liver cell damage (Hepatitis, Cirrhosis)	↑	↑

Post-hepatic (Obstructive)	Bile duct obstruction (Gallstones, Pancreatic Ca)	Normal	↑↑

Normal Serum Bilirubin: **0.2–1.0 mg/dL**; Jaundice दिखता है > 2.5 mg/dL (Scleral icterus > 3 mg/dL)।

☆ Booster Points (D.Pharmacy Competitive Exam)

- ❖ Transamination = Amino Group transfer; Coenzyme = PLP (Vitamin B_6)।
- ❖ ALT (SGPT) = Liver Specific; AST (SGOT) = Liver + Heart।
- ❖ Oxidative Deamination: Glutamate → α-KG + NH_3 (Glutamate Dehydrogenase — GDH)।
- ❖ Urea Cycle: Liver में; NH_3 + CO_2 + Aspartate → Urea; 3 ATP per Urea।
- ❖ CPS-I: Urea Cycle का Rate-limiting enzyme; NAG (N-Acetylglutamate) इसका Activator।
- ❖ Urea Cycle Steps: Carbamoyl-P → Citrulline → Argininosuccinate → Arginine → Urea।
- ❖ OTC Deficiency = सबसे common Urea Cycle defect (X-linked)।
- ❖ Decarboxylation: Histamine (Histidine), Serotonin (Tryptophan), GABA (Glutamate)।
- ❖ PKU: Phenylalanine Hydroxylase ↓ → Phenylalanine ↑ → Mental retardation।
- ❖ Alkaptonuria: Homogentisate Oxidase ↓ → Urine blackens in air।
- ❖ Albinism: Tyrosinase ↓ → No Melanin → Depigmentation।
- ❖ MSUD: Sweet maple syrup smell of urine; Branched-chain Keto Acid DH ↓।
- ❖ Bilirubin: Indirect (Unconjugated) = Albumin-bound; Direct (Conjugated) = Water-soluble।
- ❖ Pre-hepatic Jaundice: Hemolysis → Indirect Bili ↑↑।
- ❖ Obstructive Jaundice: Bile duct block → Direct Bili ↑↑, Clay-colored stool।

Topic 11: जैविक ऑक्सीकरण (Biological Oxidation)

1. परिचय (Introduction)

Biological Oxidation वह प्रक्रिया है जिसमें कार्बनिक अणुओं (Carbohydrates, Fats, Proteins) का **ऑक्सीकरण** होता है और उससे **ATP (ऊर्जा)** बनती है। इसमें दो मुख्य प्रक्रियाएँ हैं:

- **Electron Transport Chain (ETC):** Electrons का $NADH/FADH_2$ से O_2 तक स्थानांतरण।
- **Oxidative Phosphorylation:** ETC की ऊर्जा से ADP + Pi → ATP संश्लेषण।

स्थान: **Mitochondrial Inner Membrane (Cristae)**

2. Mitochondria की संरचना (Structure of Mitochondria)

- Outer Membrane: Permeable to small molecules; Porins।
- Inner Membrane (Cristae): **ETC Complex I–IV + ATP Synthase (Complex V)** — Impermeable (selective)।
- Intermembrane Space: Protons (H^+) pump होते हैं → Proton Gradient।
- Matrix: TCA Cycle, β-Oxidation, Urea Cycle (partial), Fatty Acid Oxidation।

3. Electron Transport Chain (ETC) — इलेक्ट्रॉन परिवहन श्रृंखला

3.1 ETC के Components (Complexes)

Complex	Name	Action	Prosthetic Groups
Complex I	NADH-CoQ Reductase (NADH Dehydrogenase)	NADH → CoQ (Ubiquinone); $4H^+$ pump (Matrix → IMS)	FMN, Fe-S Clusters

Complex II	Succinate-CoQ Reductase (Succinate Dehydrogenase)	$FADH_2 \rightarrow CoQ$; H^+ pump नहीं	FAD, Fe-S, Cytochrome b
Complex III	CoQ-Cytochrome c Reductase (Cytochrome bc1)	$CoQH_2 \rightarrow$ Cyt c; $4H^+$ pump	Cytochrome b, c1, Fe-S (Rieske protein)
Complex IV	Cytochrome c Oxidase	Cyt c $\rightarrow O_2$ ($\rightarrow H_2O$); $2H^+$ pump	Cytochrome a, a3, Cu A, Cu B
Complex V	ATP Synthase (F_0F_1 ATPase)	H^+ flow back $\rightarrow$ ATP synthesis	F_0 (Proton channel), F_1 (Catalytic)

3.2 Mobile Electron Carriers

- **Coenzyme Q (Ubiquinone, CoQ):** Complex I और II से electrons लेकर Complex III को देता है। Hydrophobic — Lipid bilayer में घुला।
- **Cytochrome c:** Complex III से electrons लेकर Complex IV को देता है। Water-soluble — Peripheral membrane protein।

3.3 ETC — Electron Flow Summary

NADH $\rightarrow$ Complex I $\rightarrow$ CoQ $\rightarrow$ Complex III $\rightarrow$ Cyt c $\rightarrow$ Complex IV $\rightarrow O_2$ (H_2O) **[Pumps 4+4+2 = 10 H^+]**

$FADH_2$ $\rightarrow$ Complex II $\rightarrow$ CoQ $\rightarrow$ Complex III $\rightarrow$ Cyt c $\rightarrow$ Complex IV $\rightarrow O_2$ (H_2O) **[Pumps 0+4+2 = 6 H^+]**

4. Oxidative Phosphorylation — ATP संश्लेषण

4.1 Chemiosmotic Theory (Peter Mitchell, 1961 — Nobel Prize 1978)

ETC द्वारा **Protons (H^+)** Intermembrane Space में pump होते हैं $\rightarrow$ **Proton Gradient (ΔpH) + Electrical Gradient ($\Delta\psi$) = Proton Motive Force (PMF)** बनता है।

Protons वापस Matrix में **ATP Synthase (Complex V)** के F_0 Channel के माध्यम से आते हैं $\rightarrow$ **F_1 Subunit** $\rightarrow$ **ADP + Pi** $\rightarrow$ **ATP**।

4.2 P/O Ratio — ATP Yield

Electron Donor	H^+ pumped	ATP Yield
NADH	10 H^+	2.5 ATP (Modern value; older = 3 ATP)
$FADH_2$	6 H^+	1.5 ATP (older = 2 ATP)

3.67 H^+ per ATP synthesis (F_0F_1 ATPase mechanism)।

5. Total ATP Calculation — 1 Glucose का Aerobic Oxidation

Pathway	$NADH/FADH_2$	Substrate ATP	Total ATP
Glycolysis (Cytoplasm)	2 NADH (→ 1.5 each via Malate Aspartate shuttle)	2 ATP	2+3 = 5 ATP
Pyruvate Dehydrogenase (×2)	2 NADH (×2.5)	—	5 ATP
TCA Cycle (×2 turns)	6 NADH + 2 $FADH_2$	2 GTP	15+3+2 = 20 ATP
TOTAL			30–32 ATP

Note: Cytoplasmic NADH — Malate-Aspartate Shuttle → 2.5 ATP; Glycerol-3-P Shuttle → 1.5 ATP।

6. Inhibitors of ETC और Oxidative Phosphorylation

Inhibitor	Target	Mechanism
Rotenone, Amytal	Complex I	NADH → CoQ transfer block
Malonate	Complex II	Succinate DH competitive inhibitor
Antimycin A	Complex III	CoQ → Cyt c transfer block

Cyanide (CN^-), CO, H_2S, Azide	Complex IV	Cyt c Oxidase block → O_2 नहीं ले सकता
Oligomycin	Complex V (ATP Synthase)	F_0 Channel block → H^+ नहीं जाता → ATP नहीं
Dinitrophenol (DNP), FCCP	Uncouplers	Inner Membrane का H^+ leak → PMF dissipate → ATP नहीं (Heat बनता है)

7. Uncouplers (Uncoupling Agents)

Uncouplers ETC और ATP Synthesis को अलग कर देते हैं। ETC चलता रहता है (O_2 consume) लेकिन ATP नहीं बनता — ऊर्जा **Heat** के रूप में निकलती है।

- **2,4-Dinitrophenol (DNP):** Industrial — Proton carrier। Historical weight-loss drug — Dangerous।
- **Thermogenin (UCP-1):** Natural uncoupler — Brown Adipose Tissue में; Neonates और Hibernating animals में Body Temperature maintain।
- **Thyroid Hormones (T_3, T_4):** Physiological uncoupler — Basal Metabolic Rate ↑।
- **Fatty Acids (High Concentration):** Mild uncoupler।

8. Free Radicals एवं Antioxidants

8.1 Reactive Oxygen Species (ROS)

- ETC में partial electron transfer से **Superoxide ($O_2^{\bullet -}$), Hydrogen Peroxide (H_2O_2), Hydroxyl Radical ($^\bullet OH$)** बनते हैं।
- ROS से **Oxidative Stress** → DNA damage, Lipid Peroxidation, Protein damage।

8.2 Antioxidant Defense

Antioxidant	प्रकार	कार्य

Superoxide Dismutase (SOD)	Enzyme (Mn/Cu,Zn-SOD)	$O_2^{\bullet -} \rightarrow H_2O_2$ (Dismutation)
Catalase	Enzyme (Peroxisomes)	$H_2O_2 \rightarrow H_2O + O_2$
Glutathione Peroxidase (GPx)	Enzyme (Se-dependent)	$H_2O_2 + 2GSH \rightarrow 2H_2O + GSSG$
Vitamin E (α-Tocopherol)	Non-enzymatic	Lipid Peroxidation Chain reaction तोड़ता है
Vitamin C (Ascorbic Acid)	Non-enzymatic	Free radical scavenger; Vit E regenerate
β-Carotene (Pro-Vit A)	Non-enzymatic	Singlet O_2 quencher
Glutathione (GSH)	Non-enzymatic Tripeptide	H_2O_2 reduce; Detoxification

☆ Booster Points (D.Pharmacy Competitive Exam)

- ❖ Biological Oxidation = Mitochondrial Inner Membrane (Cristae) में होती है।
- ❖ ETC: 5 Complexes (I–V) — I, III, IV H^+ pump करते हैं (Complex II नहीं)।
- ❖ Complex I (NADH DH): NADH → CoQ; Complex II (Succinate DH): $FADH_2$ → CoQ।
- ❖ Complex IV (Cytochrome c Oxidase): Final electron acceptor = $O_2 \rightarrow H_2O$।
- ❖ Complex V (ATP Synthase/F_0F_1 ATPase): Proton gradient → ATP synthesis।
- ❖ Chemiosmotic Theory (Peter Mitchell, 1961): Proton Motive Force → ATP।
- ❖ NADH → 2.5 ATP; $FADH_2$ → 1.5 ATP (Modern values)।
- ❖ 1 Glucose Aerobic Oxidation → 30–32 ATP Total।
- ❖ Cyanide, CO → Complex IV block → Cellular Asphyxia (Histotoxic Hypoxia)।
- ❖ Oligomycin → Complex V (ATP Synthase) block।

- ❖ DNP → Uncoupler → ETC चलता है, ATP नहीं बनता → Heat।
- ❖ Thermogenin (UCP-1) → Brown Adipose Tissue में Natural Uncoupler → Body Heat।
- ❖ ROS: Superoxide, H_2O_2, Hydroxyl Radical → Oxidative Damage।
- ❖ SOD → $O_2^{\bullet -}$ को detoxify; Catalase → H_2O_2 को detoxify; GPx → Se-dependent।
- ❖ Rotenone → Complex I inhibitor; Antimycin A → Complex III inhibitor।

Topic 12: खनिज (Minerals)

1. परिभाषा एवं वर्गीकरण (Definition & Classification)

खनिज (Minerals) वे अकार्बनिक (Inorganic) तत्व हैं जो शरीर के लिए सामान्य शरीर-क्रिया हेतु आवश्यक हैं। ये Vitamins की तरह **कैलोरी नहीं** देते लेकिन **Enzymes, Hormones, Blood** आदि के लिए जरूरी हैं।

वर्ग	परिभाषा	उदाहरण
Macro Minerals (Major Elements)	शरीर में > 100 mg/day आवश्यक	Ca, P, Mg, Na, K, Cl, S
Micro Minerals (Trace Elements)	शरीर में < 100 mg/day आवश्यक	Fe, Zn, Cu, I, F, Se, Mn, Co, Cr, Mo
Ultra Trace Elements	बहुत कम मात्रा में, कुछ Essential	Si, Ni, V, B, As

2. Macro Minerals — विस्तृत अध्ययन

Mineral	RDA	कार्य (Functions)	स्रोत	कमी रोग

Calcium (Ca^{2+})	1000–1200 mg/day	Bone/Teeth (99%), Blood clotting (Factor IV), Muscle contraction, Nerve impulse, Enzyme activation, Hormonal secretion	Dairy (Milk, Paneer), Fish, Green veg (Spinach), Sesame seeds	Rickets (Children), Osteoporosis, Osteomalacia, Hypocalcemia (Tetany), Muscle cramps
Phosphorus (P)	700–1250 mg/day	Bone/Teeth (85%), ATP/ADP/AMP (Energy), Phospholipids (Membranes), DNA/RNA, Buffer (Blood pH)	Dairy, Meat, Fish, Eggs, Legumes	Rare; Hypophosphatemia → Bone pain, Rickets
Magnesium (Mg^{2+})	310–420 mg/day	300+ enzyme cofactor (ATP-Mg^{2+} complex), Muscle/Nerve function, DNA/Protein synthesis, Bone formation	Green leafy veg (Chlorophyll), Nuts, Seeds, Legumes, Whole grains	Hypomagnesemia → Muscle cramps, Tetany, Arrhythmia, Weakness
Sodium (Na^{+})	1500–2300 mg/day	Major Extracellular Cation — Fluid balance, BP, Nerve impulse, Acid-base, Glucose/AA absorption (Na-dependent)	Table salt (NaCl), Processed food, Soy sauce	Hyponatremia → Confusion, Seizures; Hypernatremia → Thirst, Delirium
Potassium (K^{+})	2600–3400 mg/day	Major Intracellular Cation — Resting Membrane Potential, Heart rhythm, Muscle	Banana, Potato, Orange, Tomato, Legumes	Hypokalemia → Weakness, Arrhythmia, Paralysis;

		contraction, Na-K ATPase		Hyperkalemia → Cardiac arrest
Chloride (Cl^-)	1800–2300 mg/day	Major Extracellular Anion — Fluid balance, HCl (Gastric acid), Chloride Shift	Table salt, Meat, Vegetables	Hypochloremia → Metabolic alkalosis (Vomiting में)
Sulfur (S)	No RDA	Amino Acids (Cys, Met), Glutathione, Heparin, Vitamin B_1 structure, Connective tissue (Chondroitin sulfate)	Protein foods, Eggs, Onion, Garlic	Rare (Protein intake से मिलता है)

3. Micro Minerals (Trace Elements) — विस्तृत अध्ययन

3.1 Iron (Fe — लोहा)

पहलू	Iron (Fe)
RDA	8 mg/day (Men); 18 mg/day (Women); 27 mg/day (Pregnancy)
शरीर में Total	3.5–4 g — Hemoglobin (65%), Myoglobin (10%), Enzymes (5%), Storage (Ferritin/Hemosiderin — 20%)
कार्य	Hemoglobin (O_2 transport), Myoglobin (Muscle O_2 store), Cytochrome Enzymes, Peroxidases/Catalase, Electron transport (ETC)
Absorption	Duodenum में; Heme iron > Non-heme iron। Vit C → $Fe^{3+} \rightarrow Fe^{2+}$ → Absorption ↑। Phytates/Tannins → ↓।

Transport	Transferrin (Blood में); Storage: Ferritin (Liver, Spleen, Bone marrow), Hemosiderin
स्रोत	Heme: Meat, Fish, Liver। Non-heme: Spinach, Legumes, Fortified cereals।
कमी रोग	Iron Deficiency Anemia — Microcytic Hypochromic Anemia; Pallor, Fatigue, Koilonychia (Spoon nails)
Excess	Hemochromatosis (Iron Overload) — Liver cirrhosis, Diabetes, Bronze skin (Bronze Diabetes)

3.2 Iodine (I — आयोडीन)

पहलू	Iodine (I)
RDA	150 µg/day (Adult); 220 µg (Pregnancy); 290 µg (Lactation)
कार्य	Thyroid Hormones (T_3 = Triiodothyronine और T_4 = Thyroxine) का essential component
स्रोत	Sea fish, Seafood, Iodized Salt (सबसे important source)
Absorption	GI Tract से आसानी से absorb
कमी रोग	Goiter (घेंघा) — Thyroid Gland enlargement; Hypothyroidism; Cretinism (Congenital Hypothyroidism in children — mental retardation, dwarfism); Myxedema (adults)
Excess	Iodine-induced Thyroiditis; Hyperthyroidism (Iod-Basedow Effect)

3.3 Zinc (Zn — जस्ता)

पहलू	Zinc (Zn)
RDA	8–11 mg/day

कार्य	200+ Enzyme cofactor (Carbonic Anhydrase, Carboxypeptidase, Alcohol DH, RNA Polymerase), Insulin structure (Zn_2Insulin$_6$), Wound healing, Immune function, Taste/Smell, DNA binding proteins
स्रोत	Meat, Shellfish (Oysters — richest), Legumes, Nuts, Dairy
कमी रोग	Growth retardation, Hypogonadism, Anosmia (smell loss), Dysgeusia (taste loss), Poor wound healing, Immune deficiency; Acrodermatitis Enteropathica (Zinc transporter defect)

3.4 Copper (Cu — तांबा)

पहलू	Copper (Cu)
RDA	900 µg/day
कार्य	Ceruloplasmin (Ferroxidase — $Fe^{2+} \rightarrow Fe^{3+}$ for Transferrin), Cytochrome c Oxidase (Complex IV), SOD, Dopamine β-Hydroxylase, Tyrosinase (Melanin)
स्रोत	Liver, Oysters, Nuts, Seeds, Chocolate
Transport	Ceruloplasmin (Plasma में 95% Cu carry करता है)
कमी रोग	Menkes Kinky Hair Disease (X-linked Cu transporter defect — Kinky hair, Neurodegeneration)
Excess	Wilson's Disease (Copper Transport ATPase defect) — Cu accumulation in Liver/Brain/Cornea (Kayser-Fleischer rings)

3.5 Fluoride (F — फ्लोराइड)

पहलू	Fluoride (F)
RDA	3–4 mg/day

कार्य	Hydroxyapatite → Fluorohydroxyapatite (Bone + Teeth को कठोर बनाता है); Dental Caries prevention
स्रोत	Fluoridated water (0.7–1 ppm), Tea, Fish
कमी रोग	Dental Caries (दाँतों में सड़न)
Excess	Fluorosis — Dental Fluorosis (Mottled teeth, Brown spots); Skeletal Fluorosis (Bone density ↑, Joint pain)

3.6 Selenium (Se — सेलेनियम)

पहलू	Selenium (Se)
RDA	55 µg/day
कार्य	Glutathione Peroxidase (GPx) का essential component (Antioxidant), Thyroid Hormone metabolism (Deiodinase enzyme), Immune function
स्रोत	Brazil nuts, Sea food, Meat, Eggs
कमी रोग	Keshan Disease (Cardiomyopathy — endemic in China); Kashin-Beck Disease (Osteoarthropathy)
Excess	Selenosis — Hair loss, Nail changes, Garlic breath

4. Minerals का तुलनात्मक अध्ययन (Important Summary Table)

Mineral	Key Role	Deficiency Disease	विशेष तथ्य
Ca	Bone, Clotting	Rickets, Osteoporosis, Tetany	99% Bone में; Vit D absorption के लिए जरूरी
P	ATP, DNA, Bone	Hypophosphatemia	85% Bone में; Ca:P ratio = 2:1 (ideal)

Mg	Enzyme cofactor	Tetany, Arrhythmia	300+ enzymes; Chlorophyll में (Plants)
Fe	Hemoglobin	Microcytic Anemia	Transferrin = transport; Ferritin = storage
I	Thyroid hormones	Goiter, Cretinism	Iodized Salt सबसे important source
Zn	Enzyme cofactor (200+)	Growth retardation, Anosmia	Insulin = Zn_2Insulin$_6$; Taste/Smell
Cu	Ceruloplasmin, ETC	Menkes Disease	Wilson's Disease = Cu excess
F	Teeth/Bone hardening	Dental Caries	Fluorosis = excess; Water fluoridation
Se	GPx Antioxidant	Keshan Disease	Selenosis = excess; Brazil nuts richest

☆ Booster Points (D.Pharmacy Competitive Exam)

- ❖ Macro Minerals (> 100 mg/day): Ca, P, Mg, Na, K, Cl, S।
- ❖ Trace Minerals (< 100 mg/day): Fe, Zn, Cu, I, F, Se, Mn, Co।
- ❖ Calcium: 99% Bone/Teeth में; Blood Clotting Factor IV; Tetany — Hypocalcemia।
- ❖ Iron: Hemoglobin (65%), Myoglobin (10%), Ferritin/Storage (20%)।
- ❖ Iron Deficiency → Microcytic Hypochromic Anemia; Koilonychia (Spoon nails)।
- ❖ Iron Overload → Hemochromatosis (Bronze Diabetes — Liver, Pancreas, Skin)।
- ❖ Iodine → Thyroid Hormones (T_3, T_4); Deficiency → Goiter, Cretinism।
- ❖ Iodized Salt = Iodine का सबसे महत्वपूर्ण स्रोत।
- ❖ Zinc → 200+ Enzyme cofactor; Insulin structure; Wound healing; Anosmia।

❖ Copper → Ceruloplasmin (Ferroxidase), ETC (Complex IV), SOD।
❖ Menkes Disease: Cu transporter defect; Wilson's Disease: Cu excess → KF rings।
❖ Fluoride कमी → Dental Caries; Excess → Fluorosis (Mottled teeth)।
❖ Selenium → Glutathione Peroxidase; Keshan Disease (Cardiomyopathy)।
❖ Sodium = Major Extracellular Cation; Potassium = Major Intracellular Cation।
❖ Magnesium: Chlorophyll का घटक (Plants में Mg^{2+} = Porphyrin ring में)।

Topic 13: जल एवं इलेक्ट्रोलाइट्स (Water and Electrolytes)

1. जल (Water) — जीवन का आधार

1.1 परिभाषा एवं महत्व

जल (Water, H_2O) शरीर का सबसे अधिक मात्रा में पाया जाने वाला घटक है — शरीर के **60–70%** भाग में। यह सभी जैव-रासायनिक प्रतिक्रियाओं का माध्यम (Solvent) है।

2. शरीर में जल का वितरण (Body Water Distribution)

Compartment	कुल शरीर जल का %	मात्रा (70 kg adult)
Total Body Water (TBW)	60% of body weight	42 L
Intracellular Fluid (ICF)	40% (2/3 of TBW)	28 L — Cells के अंदर
Extracellular Fluid (ECF)	20% (1/3 of TBW)	14 L — Cells के बाहर

→ Plasma (Intravascular)	5% (1/4 of ECF)	3.5 L
→ Interstitial Fluid	15% (3/4 of ECF)	10.5 L — Cells के बीच
→ Transcellular Fluid	< 1%	CSF, Synovial, Pleural, Peritoneal

3. जल के कार्य (Functions of Water)

- **Solvent:** सभी biochemical reactions का medium।
- **Transport:** Nutrients, Hormones, Gases, Waste products का परिवहन।
- **Temperature Regulation:** High specific heat (1 cal/g/°C) + Evaporation → Body temperature control।
- **Lubricant:** Joints (Synovial fluid), Organs (Pleural, Pericardial fluid)।
- **Biochemical Reactions:** Hydrolysis, Condensation reactions में प्रत्यक्ष भाग।
- **Acid-Base Balance:** Buffer systems में।
- **Digestion:** Saliva, Gastric juice, Intestinal secretions में।

4. जल का संतुलन (Water Balance — Intake vs Output)

Water Intake (Daily ~ 2500 mL)	Water Output (Daily ~ 2500 mL)
पीना (Drinking water): 1200–1500 mL	Urine: 1200–1500 mL
भोजन (Food water): 700–1000 mL	Sweat (Perspiration): 500 mL
Metabolic Water (Oxidation water): 200–300 mL	Exhaled air (Lungs): 350 mL
	Feces: 150 mL

Note: Metabolic Water = Glucose/Fat Oxidation से उत्पन्न जल। Desert animals जैसे Kangaroo Rat इसी पर जीते हैं।

5. जल का नियमन (Regulation of Water Balance)

5.1 Thirst Mechanism (प्यास)

- Plasma Osmolality ↑ (280–295 mOsm/kg) या Blood Volume ↓ → **Hypothalamus Thirst Centre** → Drinking।
- Osmoreceptors (Hypothalamus में) → ADH Secretion।

5.2 ADH (Antidiuretic Hormone / Vasopressin)

- Secreted by: **Posterior Pituitary** (Synthesized in Hypothalamus — Supraoptic nucleus)।
- Action: Kidney Collecting Duct + Distal Tubule में **Aquaporin-2** channels insert → Water reabsorption ↑ → Urine concentrated।
- Stimuli: Plasma Osmolality ↑, Blood Volume ↓, Angiotensin II, Nicotine, Stress।
- Inhibitors: Alcohol → ADH ↓ → Diuresis (इसलिए Alcohol से Dehydration)।
- SIADH (Syndrome of Inappropriate ADH): ADH excess → Water retention → Hyponatremia।
- Diabetes Insipidus: ADH absent → Dilute urine, Polyuria।

5.3 RAAS (Renin-Angiotensin-Aldosterone System)

- Blood Volume ↓ / BP ↓ → Kidney (JGA) → **Renin** → Angiotensin I → ACE → **Angiotensin II** → Aldosterone।
- Aldosterone (Adrenal Cortex) → Kidney → **Na^+ + H_2O reabsorption** ↑, K^+ excretion ↑।

6. Electrolytes — परिभाषा एवं वर्गीकरण

Electrolytes वे Ions हैं जो जल में घुलने पर आवेशित (Charged) Particles बनाते हैं। ये **Cations (+)** और **Anions (-)** के रूप में होते हैं।

Electrolyte	ICF में (mEq/L)	ECF में (mEq/L)
Na^+ (Sodium)	12 (Low)	142 (High) — Major ECF Cation

K^+ (Potassium)	150 (High) — Major ICF Cation	4.0–5.0 (Low)
Ca^{2+} (Calcium)	~0.0001 free	~2.5 mmol/L (Serum)
Mg^{2+} (Magnesium)	~15-20 (High)	~1.0 (Low)
Cl^- (Chloride)	~4 (Low)	103 (High) — Major ECF Anion
HCO_3^- (Bicarbonate)	~10 (Low)	24–28 (High) — Second major ECF Anion
HPO_4^{2-} (Phosphate)	~100 (High) — Major ICF Anion	~2 (Low)
$Protein^-$	~54 (High)	~16 (Low)

Gibbs-Donnan Equilibrium: Proteins (Non-diffusible) → Unequal distribution of diffusible ions।

7. Dehydration (निर्जलीकरण)

7.1 परिभाषा एवं वर्गीकरण

Dehydration — शरीर में जल की कमी। तीन प्रकार:

प्रकार	Osmolality	कारण एवं Features
Isotonic Dehydration (Isonatremic)	Normal (280–295 mOsm/kg)	Water और Electrolytes दोनों equal loss (Diarrhea, Vomiting, Burns)
Hypotonic Dehydration (Hyponatremic)	Low (< 280 mOsm/kg)	Na^+ loss > Water loss (Diuretics, Adrenal insufficiency)
Hypertonic Dehydration (Hypernatremic)	High (> 295 mOsm/kg)	Water loss > Na^+ loss (Fever, Diabetes Insipidus, Sweating)

7.2 Severity of Dehydration

Grade	Body Weight Loss	Signs

Mild	< 5%	Thirst, Slightly reduced Urine output
Moderate	5–10%	Dry mouth, Sunken eyes, Skin turgor ↓, Tachycardia
Severe	> 10%	Lethargy, Sunken fontanelle (infants), Hypotension, Oliguria, Shock

8. ORT — Oral Rehydration Therapy

8.1 परिभाषा

ORT (Oral Rehydration Therapy) — Dehydration को मुँह से तरल पदार्थ देकर ठीक करने की विधि।

WHO ORS Formula (Standard): **1L पानी + NaCl (2.6g) + KCl (1.5g) + Trisodium Citrate (2.9g) + Glucose (13.5g)**

8.2 ORS कार्य करने का सिद्धांत

- **Glucose-Na^+ Co-transport:** Small Intestine में Glucose और Na^+ एक साथ absorb होते हैं (SGLT-1 Transporter)।
- Na^+ absorption → Osmotic gradient → **Water automatically absorb**।
- Glucose Diarrhea को नहीं रोकता — लेकिन Absorption बढ़ाता है।

8.3 ORT की विशेषताएँ

- WHO ने ORT को **'20th Century's Greatest Medical Advance'** माना।
- Rice water, Coconut water, Lassi + Salt — घरेलू ORT।
- Severe Dehydration में IV fluids (Normal Saline, Ringer's Lactate) जरूरी।

9. Acid-Base Balance — संक्षिप्त

Normal Blood pH: **7.35–7.45**। pH < 7.35 = **Acidosis**; pH > 7.45 = **Alkalosis**।

Disorder	pH	Cause
Metabolic Acidosis	< 7.35, HCO_3^- ↓	Diabetic Ketoacidosis, Lactic Acidosis, Diarrhea, Renal Failure
Metabolic Alkalosis	> 7.45, HCO_3^- ↑	Vomiting, Antacid excess, Diuretics (K^+ loss)
Respiratory Acidosis	< 7.35, CO_2 ↑ (pCO_2 ↑)	Hypoventilation, COPD, Pneumonia
Respiratory Alkalosis	> 7.45, CO_2 ↓ (pCO_2 ↓)	Hyperventilation, Anxiety, High Altitude

Buffer Systems: **HCO_3^-/H_2CO_3** (most important Blood buffer); **Phosphate buffer** (Urine में); **Protein buffer** (Intracellular)।

☆ Booster Points (D.Pharmacy Competitive Exam)

- ❖ Total Body Water = 60% of body weight; ICF = 40%; ECF = 20%।
- ❖ Plasma = 5% body weight; Interstitial = 15%; Transcellular < 1%।
- ❖ ADH (Vasopressin): Posterior Pituitary — Water reabsorption ↑ (Aquaporin-2)।
- ❖ Diabetes Insipidus: ADH absent → Polyuria, Dilute urine।
- ❖ SIADH: ADH excess → Water retention → Hyponatremia।
- ❖ Aldosterone (Adrenal Cortex): $Na^+ + H_2O$ reabsorption ↑, K^+ excretion ↑।
- ❖ Na^+ = Major ECF Cation; K^+ = Major ICF Cation।
- ❖ Cl^- = Major ECF Anion; HPO_4^{2-} = Major ICF Anion।
- ❖ Normal Blood pH = 7.35–7.45; Acidosis < 7.35; Alkalosis > 7.45।
- ❖ ORS (WHO): Glucose + NaCl + KCl + Trisodium Citrate + Water।
- ❖ ORT Principle: Glucose-Na^+ Co-transport (SGLT-1) → Water automatically absorbs।

- ❖ Metabolic Water: Glucose/Fat Oxidation से 200–300 mL/day बनता है।
- ❖ Isotonic Dehydration: Equal water + Na^+ loss (Diarrhea, Vomiting)।
- ❖ Hypertonic Dehydration: Water loss > Na^+ loss → Plasma Osmolality ↑।
- ❖ HCO_3^-/H_2CO_3 = सबसे महत्वपूर्ण Blood Buffer System।

Topic 14: जैव-प्रौद्योगिकी का परिचय (Introduction to Biotechnology)

1. परिभाषा (Definition)

Biotechnology (जैव-प्रौद्योगिकी) वह विज्ञान है जो **जीवित जीवों (Living Organisms)** या उनके **उत्पादों** का उपयोग मानव कल्याण हेतु — विशेषकर **चिकित्सा, कृषि, उद्योग** में — करता है।

WHO परिभाषा: **"Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents."**

Modern Biotechnology — **Recombinant DNA Technology (rDNA)** पर आधारित।

2. Biotechnology के प्रकार

Color Code	क्षेत्र	उदाहरण
Red Biotechnology	Pharmaceutical/Medical — Health	Vaccines, Antibiotics, Gene therapy, Monoclonal Antibodies
Green Biotechnology	Agricultural	GM crops (Bt Cotton, Golden Rice), Biopesticides
Blue Biotechnology	Marine/Aquatic	Algae-based fuels, Aquaculture
White Biotechnology	Industrial/Environmental	Biofuels, Bioplastics, Enzyme production

Yellow Biotechnology	Food/Nutrition	Fermentation, Probiotics
Grey Biotechnology	Environmental	Bioremediation, Pollution control

3. Recombinant DNA Technology (rDNA / Genetic Engineering)

3.1 परिभाषा

Recombinant DNA Technology वह तकनीक है जिसमें विभिन्न स्रोतों के DNA को **in vitro** जोड़कर नया DNA (Recombinant DNA) बनाया जाता है और इसे Host Cell में Insert करके **Desired Protein** उत्पन्न किया जाता है।

3.2 rDNA Technology के मुख्य Steps

- **Step 1 — Gene of Interest की पहचान:** Desired gene select करें जो required protein code करता है।
- **Step 2 — Gene को cut करें:** Restriction Endonucleases (Molecular Scissors) द्वारा।
- **Step 3 — Vector में insert करें:** DNA Ligase (Molecular Glue) द्वारा Plasmid/Virus Vector में।
- **Step 4 — Host Cell में Transform:** Recombinant DNA को Bacteria/Yeast/Mammalian Cell में।
- **Step 5 — Selection:** Antibiotic resistance markers द्वारा Transformed cells select।
- **Step 6 — Expression + Harvesting:** Host cell में Protein produce → Purify।

3.3 Key Tools of rDNA Technology

Tool	Type	कार्य

Restriction Endonucleases (Restriction Enzymes)	Type II RE — Most used	DNA को Specific Sequences (Palindromic) पर cut करते हैं। 'Molecular Scissors'। जैसे: EcoRI, HindIII, BamHI।
DNA Ligase	Enzyme	Cut ends को जोड़ता है — Phosphodiester Bonds। 'Molecular Glue'।
Vectors (Plasmids, Viruses)	DNA carriers	Recombinant DNA को Host में carry करते हैं। Plasmid pBR322 — classic।
Host Cells	Bacterial, Yeast	E. coli (most common), Yeast (Saccharomyces), CHO cells।
Gel Electrophoresis	Separation technique	DNA Fragments को size के आधार पर separate करना।
PCR (Polymerase Chain Reaction)	DNA amplification	DNA की millions of copies बनाना in vitro। Kary Mullis 1983।
Southern Blotting	Detection	DNA में specific sequences detect करना।
Northern Blotting	Detection	RNA detect करना।
Western Blotting	Detection	Protein detect करना।

4. PCR (Polymerase Chain Reaction)

PCR — DNA के किसी specific region की **Millions of copies** बनाने की तकनीक। Kary Mullis (1983) ने develop किया। **Nobel Prize 1993**।

4.1 PCR के Steps (3 Steps प्रति Cycle)

- **Step 1 — Denaturation:** 94°C — Double-stranded DNA → Single strands (H-bonds टूटते हैं)।
- **Step 2 — Annealing:** 50–65°C — Primers DNA template से bind होते हैं।

- **Step 3 — Extension:** 72°C — **Taq Polymerase** (Thermostable — Thermus aquaticus से) → New DNA strand synthesis!
- 30 Cycles → 2^{30} = ~1 Billion copies!!

4.2 PCR के उपयोग (Applications)

- Forensic Science (DNA Fingerprinting), Paternity Testing
- Disease Diagnosis (HIV, TB, COVID-19 RT-PCR)
- Genetic Disease Detection (Prenatal)
- Evolutionary Biology
- Ancient DNA studies

5. Pharmaceutical Biotechnology — उत्पाद

Product	Host System	Medical Use
Recombinant Insulin (Humulin)	E. coli (Gene: Human Insulin A+B chains)	Type 1 Diabetes Mellitus — सबसे पहला rDNA drug (1982)
Recombinant Erythropoietin (Epoetin)	CHO Cells	Anemia (CKD, Cancer Chemotherapy में)
Recombinant Growth Hormone (Somatropin)	E. coli	Growth Hormone deficiency, Dwarfism
Recombinant Factor VIII	CHO Cells	Hemophilia A
Recombinant Factor IX	CHO Cells	Hemophilia B
Recombinant Hepatitis B Vaccine	Yeast (Saccharomyces cerevisiae)	Hepatitis B Prevention — HBsAg
Recombinant Streptokinase	E. coli	Myocardial Infarction — Thrombolysis

Interferon α-2b	E. coli	Hepatitis C, Cancer, Viral infections
Monoclonal Antibodies (mAbs)	Hybridoma Technology	Cancer (Herceptin, Rituximab), Autoimmune, Transplant

6. Monoclonal Antibodies (mAbs)

6.1 परिभाषा

Monoclonal Antibodies — एक single clone of B-cells द्वारा उत्पन्न **identical Antibodies** जो एक specific Antigen को target करती हैं।

6.2 Hybridoma Technology (Kohler & Milstein, 1975 — Nobel Prize 1984)

- **Step 1:** Antigen inject → Mouse → Antibody-producing B-cells।
- **Step 2:** B-cells + Myeloma Cells (Cancer cells) → **Hybridoma cells** (Fusion by PEG)।
- **Step 3:** Hybridoma → HAT medium में select → Clone → **Monoclonal Antibody**।

6.3 mAbs के Pharmaceutical Applications

mAb	Target	Use
Trastuzumab (Herceptin)	HER-2 Receptor	Breast Cancer
Rituximab (Rituxan)	CD20 (B-cells)	Non-Hodgkin Lymphoma, Rheumatoid Arthritis
Bevacizumab (Avastin)	VEGF	Cancer (Anti-angiogenesis)
Adalimumab (Humira)	TNF-α	Rheumatoid Arthritis, Crohn's Disease
Pembrolizumab (Keytruda)	PD-1 Checkpoint	Cancer Immunotherapy
Infliximab (Remicade)	TNF-α	Rheumatoid Arthritis, IBD

7. Gene Therapy

Gene Therapy — किसी Genetic Disease के इलाज हेतु **Normal Gene** को रोगी की कोशिकाओं में Insert करना।

- ➤ **Somatic Gene Therapy:** Body Cells में — non-inheritable।
- ➤ **Germline Gene Therapy:** Germ cells में — inheritable (ethically controversial)।
- ➤ Vectors: Retroviruses, Adenoviruses, Adeno-Associated Viruses (AAV), Lentivirus।
- ➤ Clinical use: ADA Deficiency (Adenosine Deaminase — Bubble Boy disease), Hemophilia, Muscular Dystrophy।

8. CRISPR-Cas9 — Gene Editing

CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats) — **Gene Editing** की revolutionary technique।

- ➤ Developed by: **Jennifer Doudna और Emmanuelle Charpentier** (Nobel Prize 2020)।
- ➤ Guide RNA (sgRNA) → Specific DNA location तक Cas9 nuclease को guide करती है → DNA cut → Edit।
- ➤ Applications: Genetic diseases, Cancer, Sickle cell disease, Agriculture।

☆ **Booster Points** (D.Pharmacy Competitive Exam)
❖ Biotechnology = Living organisms का उपयोग human welfare के लिए।
❖ Red Biotechnology = Medical/Pharma; Green = Agriculture; White = Industrial।
❖ Recombinant DNA Technology: RE (cut) + Ligase (join) + Vector (carry) + Host (express)।
❖ Restriction Enzymes = 'Molecular Scissors'; DNA Ligase = 'Molecular Glue'।
❖ PCR: Kary Mullis 1983; Nobel 1993; Taq Polymerase (Thermostable)।
❖ PCR Steps: Denaturation (94°C) → Annealing (50–65°C) → Extension (72°C)।

❖ सबसे पहला rDNA Drug: Recombinant Insulin (Humulin) — 1982 — E. coli।
❖ Recombinant Hepatitis B Vaccine — Yeast (S. cerevisiae) में HBsAg।
❖ Monoclonal Antibodies: Hybridoma Technology (Kohler & Milstein, 1975; Nobel 1984)।
❖ Hybridoma = B-cell + Myeloma cell (fusion by PEG) → HAT medium select।
❖ Trastuzumab (Herceptin): HER-2+ Breast Cancer।
❖ Adalimumab (Humira): TNF-α inhibitor — RA, Crohn's Disease।
❖ CRISPR-Cas9: Gene Editing — Doudna & Charpentier (Nobel 2020)।
❖ Gene Therapy: Somatic (non-inheritable) vs Germline (inheritable)।
❖ Western Blot = Protein; Southern = DNA; Northern = RNA।

Topic 15: Organ Function Tests — KFT, LFT, Lipid Profile

भाग A — Kidney Function Tests (KFT / RFT)

Kidney Function Tests (KFT) — जिन्हें Renal Function Tests (RFT) भी कहते हैं — Kidney की कार्यक्षमता का मूल्यांकन करते हैं।

A.1 Serum Creatinine

Parameter	विवरण
Normal Range	Men: 0.7–1.2 mg/dL; Women: 0.5–1.0 mg/dL
Source	Creatine Phosphate (Muscle) का Spontaneous Degradation → Creatinine
Significance	Glomerular Filtration का sensitive marker। GFR ↓ → Creatinine ↑। Kidney Mass का indicator।
Clearance	Creatinine Clearance ≈ GFR (Normal: 90–125 mL/min)

Clinical	Renal Failure, CKD, AKI में ↑। Muscle wasting में ↓।

A.2 Blood Urea Nitrogen (BUN) / Serum Urea

Parameter	विवरण
Normal Range	BUN: 7–20 mg/dL; Urea: 15–40 mg/dL
Source	Protein Metabolism → Amino Acid Deamination → Urea Cycle (Liver में)
Significance	Kidney excretion + Protein intake दोनों reflect करता है।
BUN:Creatinine Ratio	Normal: 10:1 to 20:1; Pre-renal azotemia > 20:1; Renal azotemia < 10:1
Azotemia	Blood में Urea/Nitrogen ↑ = Azotemia; Uremia = Azotemia + symptoms

A.3 Serum Uric Acid

Parameter	विवरण
Normal Range	Men: 3.5–7.2 mg/dL; Women: 2.6–6.0 mg/dL
Source	Purine Nucleotide Catabolism का End Product (Xanthine Oxidase द्वारा)
Significance	Gout में ↑ (Uric Acid Crystals → Joint में). Lesch-Nyhan Syndrome (HGPRT deficiency)।
Drug	Allopurinol → Xanthine Oxidase inhibit → Uric Acid ↓

A.4 Glomerular Filtration Rate (GFR)

Parameter	विवरण
Normal GFR	90–125 mL/min (Adult)
Measurement	Inulin Clearance (Gold Standard); Creatinine Clearance (Practical)

CKD Staging (eGFR)	Stage 1: >90; Stage 2: 60–89; Stage 3: 30–59; Stage 4: 15–29; Stage 5 (ESRD): <15 mL/min

A.5 Complete KFT Panel — Normal Values

Test	Normal Range	Elevated in
Serum Creatinine	0.7–1.2 mg/dL	Renal Failure, CKD, AKI
BUN (Blood Urea N)	7–20 mg/dL	Renal disease, High protein diet, Dehydration
Serum Urea	15–40 mg/dL	Renal Failure, Post-renal obstruction
Uric Acid	3.5–7.2 mg/dL	Gout, Lesch-Nyhan, Renal Failure, Diuretics
GFR (eGFR)	90–125 mL/min	↓ in CKD (Inverse: GFR↓ = disease ↑)
Serum Electrolytes (Na+)	136–145 mEq/L	Hypernatremia = Dehydration
Serum K+	3.5–5.0 mEq/L	Hyperkalemia = CKD, Adrenal insufficiency
Serum Ca^{2+}	8.5–10.5 mg/dL	Hypercalcemia = Malignancy, Hyperparathyroidism
24-hr Urine Protein	< 150 mg/day	Nephrotic Syndrome > 3.5 g/day

भाग B — Liver Function Tests (LFT)

LFT — Liver की विभिन्न कार्यक्षमताओं का Assessment — Hepatocellular damage, Cholestasis, Synthetic function।

B.1 LFT Panel — सम्पूर्ण विवरण

Test	Normal Range	Clinical Significance

ALT (SGPT)	7–40 U/L	Hepatitis, Liver cell damage — Most specific Liver enzyme
AST (SGOT)	10–40 U/L	Hepatitis + Myocardial Infarction; AST:ALT >2:1 = Alcoholic Liver Disease
ALP (Alkaline Phosphatase)	44–147 U/L	Cholestasis (bile duct obstruction), Bone disease, Liver disease
GGT (Gamma-Glutamyl Transferase)	0–51 U/L	Most sensitive Liver enzyme; Alcoholism, Drug toxicity
Total Bilirubin	0.3–1.2 mg/dL	Jaundice > 2.5 mg/dL; Scleral Icterus > 3 mg/dL
Direct Bilirubin (Conjugated)	0–0.3 mg/dL	↑ in Hepatic + Post-hepatic Jaundice
Indirect Bilirubin (Unconjugated)	0.2–0.8 mg/dL	↑ in Pre-hepatic (Hemolytic) Jaundice
Total Protein	6–8 g/dL	↓ in Liver failure, Malnutrition, Nephrotic syndrome
Albumin	3.5–5.0 g/dL	Synthetic function — ↓ in Chronic Liver Disease, Malnutrition
Globulin	2–3.5 g/dL	↑ in Chronic Infection, Liver Cirrhosis
A:G Ratio (Albumin:Globulin)	1.2:1 to 2.2:1	Reversed in Cirrhosis, Chronic infection
PT (Prothrombin Time)	11–14 seconds	Synthetic function — ↑ in Liver Failure (Factors II, V, VII, X ↓)

B.2 विशेष LFT Findings

Pattern	ALT/AST	ALP/GGT

Hepatocellular Damage (Hepatitis, Drug toxicity)	↑↑↑ (Mainly)	Mildly ↑
Cholestasis (Bile duct obstruction)	Mildly ↑	↑↑↑ (Mainly)
Mixed (Cirrhosis)	↑ Both	↑ Both
Alcoholic Liver Disease	AST:ALT > 2:1	GGT ↑↑

भाग C — Lipid Profile Tests

C.1 Lipid Profile Panel

Test	Normal Range	Interpretation
Total Cholesterol	< 200 mg/dL (Desirable) 200–239 = Borderline ≥ 240 = High	Cardiovascular Risk Assessment
LDL Cholesterol ('Bad Cholesterol')	< 100 mg/dL (Optimal) 100–129 = Near Optimal 130–159 = Borderline ≥ 160 = High	Atherosclerosis risk; Target in CAD patients < 70 mg/dL
HDL Cholesterol ('Good Cholesterol')	Men: ≥ 40 mg/dL Women: ≥ 50 mg/dL > 60 = Protective	↑ HDL = Protective; ↓ HDL = CAD risk ↑
Triglycerides (TG)	< 150 mg/dL (Normal) 150–199 = Borderline 200–499 = High ≥ 500 = Very High	Pancreatitis risk at > 500 mg/dL
VLDL Cholesterol	2–30 mg/dL	VLDL = TG/5 (Friedewald equation)
Non-HDL Cholesterol	< 130 mg/dL	Total Cholesterol − HDL; Includes LDL+VLDL+IDL

C.2 LDL Calculation — Friedewald Equation

LDL = Total Cholesterol – HDL – (TG/5) [Valid only if TG < 400 mg/dL]

जब TG > 400 mg/dL → Direct LDL Measurement (Homogeneous method) जरूरी।

C.3 Cardiac Risk Ratio

Ratio	Interpretation
Total Cholesterol / HDL	< 4.0 = Desirable; > 5.0 = High Risk
LDL / HDL	< 3.0 = Good; > 3.5 = Risk
TG / HDL	< 2.0 = Good; > 3.5 = Insulin Resistance risk

C.4 Dyslipidemia (Fredrickson Classification — WHO)

Type	Lipid Elevated	Cause
Type I (Rare)	Chylomicrons ↑, TG ↑↑	Lipoprotein Lipase (LPL) या Apo-CII deficiency
Type IIa (Common)	LDL ↑, Cholesterol ↑	Familial Hypercholesterolemia (LDL receptor defect)
Type IIb	LDL ↑ + VLDL ↑	Combined Hyperlipidemia
Type III	IDL ↑	Familial Dysbetalipoproteinemia (Apo-E2 defect)
Type IV (Common)	VLDL ↑, TG ↑	Hypertriglyceridemia — DM, Obesity, Alcohol
Type V	Chylomicrons ↑ + VLDL ↑	LPL deficiency + VLDL overproduction

☆ Booster Points (D.Pharmacy Competitive Exam)

- Serum Creatinine: Men 0.7–1.2; Women 0.5–1.0 mg/dL — Best GFR marker।

- ❖ BUN Normal: 7–20 mg/dL; BUN:Creatinine > 20:1 = Pre-renal Azotemia।
- ❖ Uric Acid ↑ → Gout (Monosodium Urate crystals in joints)।
- ❖ GFR < 15 mL/min = End Stage Renal Disease (ESRD / CKD Stage 5)।
- ❖ ALT (SGPT) = Most specific Liver enzyme; Normal: 7–40 U/L।
- ❖ AST:ALT > 2:1 = Alcoholic Liver Disease।
- ❖ GGT ↑ = Alcoholism का most sensitive marker।
- ❖ Total Bilirubin Normal: 0.3–1.2 mg/dL; Jaundice > 2.5 mg/dL।
- ❖ PT (Prothrombin Time) ↑ = Liver Synthetic Function ↓।
- ❖ Total Cholesterol < 200 = Desirable; LDL < 100 = Optimal।
- ❖ HDL > 60 mg/dL = Protective (Cardioprotective); < 40 = Risk।
- ❖ TG > 500 mg/dL = Pancreatitis risk।
- ❖ Friedewald: LDL = TC − HDL − TG/5 (Valid: TG < 400 mg/dL)।
- ❖ Familial Hypercholesterolemia = LDL Receptor Defect → LDL ↑ (Type IIa)।
- ❖ LPL Deficiency → Chylomicrons ↑ (Type I Hyperlipoproteinemia)।

Topic 16: रक्त एवं मूत्र की विकृति विज्ञान (Pathology of Blood and Urine)

भाग A — Lymphocytes और Platelets

A.1 Lymphocytes (लिम्फोसाइट्स)

Lymphocytes — Agranulocytes (WBC) — Immune System की मुख्य कोशिकाएँ।

पहलू	Lymphocytes

Normal Count	1000–4000/µL (Total WBC का 20–40%)
Types	T-Lymphocytes (60–70%), B-Lymphocytes (10–20%), Natural Killer (NK) Cells (5–15%)
T-Lymphocyte Types	CD4+ T-Helper Cells (Th1/Th2), CD8+ Cytotoxic T-cells (CTL), T-Regulatory Cells (Treg), Memory T-cells
B-Lymphocyte कार्य	Antibody (Immunoglobulin) उत्पन्न करते हैं। Plasma Cells में differentiate होते हैं।
NK Cells	Virus-infected cells और Tumour cells को बिना specific Antigen recognition के kill करते हैं।
Origin	Bone Marrow (Common lymphoid precursor); T-cells → Thymus में mature; B-cells → Bone marrow में।

Lymphocyte Abnormalities

स्थिति	परिभाषा	कारण
Lymphocytosis	Lymphocytes > 4000/µL	Viral infections (EBV/Mononucleosis, CMV, Whooping cough, CLL)
Lymphocytopenia	Lymphocytes < 1000/µL	HIV/AIDS, Corticosteroids, Radiation, Severe malnutrition, Aplastic Anemia
Lymphoma	Malignant lymphocytes — Solid tumor	Hodgkin's Lymphoma (Reed-Sternberg cells), Non-Hodgkin's Lymphoma
Leukemia	Malignant lymphocytes — Circulating	ALL (Acute Lymphoblastic Leukemia), CLL (Chronic Lymphocytic Leukemia)

A.2 Platelets (Thrombocytes — प्लेटलेट्स)

Platelets — Non-nucleated Blood cells — Blood Clotting (Hemostasis) में मुख्य भूमिका।

पहलू	Platelets
Normal Count	1.5–4.0 × 10^5/µL (150,000–400,000/µL)
Origin	Bone Marrow में Megakaryocytes से (Thrombopoietin — TPO द्वारा stimulate)
Size	2–3 µm — Smallest Blood cells
Lifespan	8–12 days; Removal: Spleen में
कार्य	Primary Hemostasis (Platelet Plug formation), Secondary Hemostasis support, Clot Retraction, Wound healing
Contents	Alpha Granules (von Willebrand factor, Fibrinogen, Factor V), Dense Granules (ADP, Serotonin, Calcium)

Platelet Disorders

रोग	Platelet Count	कारण/विशेषता
Thrombocytopenia	< 150,000/µL	ITP, Aplastic Anemia, DIC, Drug-induced (Heparin→HIT), Dengue, Malaria
Thrombocytosis	> 400,000/µL	Reactive (Infection, Iron deficiency) या Autonomous (ET — Essential Thrombocythemia)
ITP (Immune Thrombocytopenic Purpura)	< 100,000/µL	Anti-platelet Antibodies — Purpura, Petechiae, Bleeding
DIC (Disseminated Intravascular Coagulation)	↓ (Consumed)	Sepsis, Trauma → Clotting + Bleeding simultaneously

von Willebrand Disease	Normal Count (but Dysfunction)	vWF deficiency → Poor platelet adhesion; Most common hereditary bleeding disorder
Bleeding Time (BT)	Normal: 2–7 min	↑ in Thrombocytopenia, von Willebrand, Aspirin use

भाग B — Erythrocytes (RBCs) — सामान्य एवं असामान्य कोशिकाएँ

B.1 Normal Erythrocyte Parameters

Parameter	Normal Range	Significance
RBC Count	Men: 4.5–5.5 million/µL Women: 3.8–4.8 million/µL	Anemia में ↓; Polycythemia में ↑
Hemoglobin (Hb)	Men: 13.5–17.5 g/dL Women: 12.0–15.5 g/dL	O_2 Carrying Capacity
Hematocrit (PCV)	Men: 40–54% Women: 36–47%	Blood का RBC %
MCV (Mean Corpuscular Vol)	80–100 fL	Macrocytic >100, Microcytic <80
MCH (Mean Corp. Hb)	27–33 pg	Hypochromic < 27 pg
MCHC	32–36 g/dL	Hypochromic < 32
RBC Lifespan	120 days	Spleen में destroy; Hemolytic Anemia में ↓
ESR (Erythrocyte Sedimentation Rate)	Men: <15 mm/hr; Women: <20 mm/hr	↑ in Inflammation, Infection, Anemia

B.2 Abnormal RBC Cells — Poikilocytosis

Abnormal RBC	Description	Associated Disease

Sickle Cells (Drepanocytes)	Crescent/Sickle shape — HbS mutation	Sickle Cell Anemia (HbS/HbS) — β-Globin Glu→Val at position 6
Target Cells (Codocytes)	Bulls-eye / shooting target appearance	Thalassemia, Liver Disease, Iron Deficiency, HbC Disease
Spherocytes	Spherical (no central pallor)	Hereditary Spherocytosis (Spectrin defect), Autoimmune Hemolytic Anemia
Elliptocytes (Ovalocytes)	Oval/Elliptical shape	Hereditary Elliptocytosis (Spectrin/Protein 4.1 defect)
Schistocytes (Fragmented)	RBC fragments	Microangiopathic Hemolytic Anemia, TTP, DIC, Prosthetic Heart Valves
Acanthocytes (Spur cells)	Irregular spikes (3–12 spicules)	Abetalipoproteinemia, Liver Disease, McLeod Syndrome
Echinocytes (Burr cells)	Regular 10–30 spicules	Uremia (CRF), Pyruvate Kinase Deficiency
Tear-drop cells (Dacrocytes)	Tear-drop shape	Myelofibrosis, Thalassemia, Myelophthisic Anemia
Nucleated RBCs (nRBC)	Immature RBC with nucleus	Hemolytic Anemia, Leukemia, Severe Anemia
Rouleaux Formation	Coin-stack stacking of RBC	Multiple Myeloma, Inflammatory states
Howell-Jolly Bodies	Nuclear remnants (dark dot) in RBC	Splenectomy, Megaloblastic Anemia, Hemolytic Anemia
Basophilic Stippling	Blue granules in RBC	Lead Poisoning, Thalassemia, Hemolytic Anemia

B.3 Anemias का वर्गीकरण (Classification of Anemias)

Type	MCV/Characteristics	कारण
Microcytic Hypochromic (MCV < 80 fL)	Small, Pale RBC	Iron Deficiency (Most common), Thalassemia, Sideroblastic Anemia, ACD
Normocytic Normochromic (MCV 80–100 fL)	Normal size, Normal color	Aplastic Anemia, Hemolytic Anemia, Acute Blood Loss
Macrocytic (MCV > 100 fL)	Large RBC	Megaloblastic Anemia (B12/Folate deficiency), Liver Disease, Hypothyroidism

भाग C — Normal एवं Abnormal Constituents of Urine

C.1 Normal Urine Properties

Property	Normal Value
Volume	1000–2000 mL/day (Average 1500 mL)
Color	Pale Yellow to Amber — Urochrome pigment (Urobilin)
pH	4.5–8.0 (Average 6.0) — Diet के अनुसार
Specific Gravity	1.010–1.030
Odor	Aromatic (Fresh); Ammoniacal (On standing)
Osmolality	300–1000 mOsm/kg
Turbidity	Clear (Fresh)

C.2 Normal Constituents of Urine

Constituent	Amount/Day	Source

Urea	20–35 g/day (Largest organic constituent)	Protein catabolism → Urea Cycle
Creatinine	1–1.5 g/day	Creatine Phosphate spontaneous degradation
Uric Acid	0.5–1.0 g/day	Purine catabolism
Na^+	40–220 mEq/day	Diet dependent
K^+	25–100 mEq/day	ICF major cation
Cl^-	110–250 mEq/day	Major ECF anion excretion
Phosphate	0.7–1.4 g/day	Bone + Metabolism
Ammonia (NH_4^+)	30–50 mEq/day	Renal tubular production (AA deamination)
Water	1000–1500 mL/day	Glomerular filtration + selective reabsorption

C.3 Abnormal Constituents of Urine (Pathological)

Constituent	Condition	Cause	Test
Glucose (Glycosuria)	DM, Renal Glycosuria	Blood Glucose > Renal Threshold (180 mg/dL); or ↓ Renal Threshold	Benedict's Test, Glucometer dipstick
Protein (Proteinuria)	Nephrotic Syndrome, Glomerulonephritis	GFR ↑ Permeability; > 150 mg/day = Proteinuria; > 3.5 g/day = Nephrotic range	Heller's Test (HNO_3), Dipstick

Ketones (Ketonuria)	DKA, Starvation, High Fat Diet	Excess Ketone Body production → Overflow	Rothera's Test (Na Nitroprusside), Dipstick
Blood (Hematuria)	Urinary Tract Infection, Renal Calculi, Trauma	RBC in urine — Macro (visible) या Micro	Dipstick (Benzidine) + Microscopy
Hemoglobin (Hemoglobinuria)	Hemolytic Anemia, Blackwater fever	Intravascular Hemolysis → Free Hb in Blood → Urine	Guaiac Test, Spectroscopy
Bilirubin (Bilirubinuria)	Hepatic + Obstructive Jaundice	Conjugated (Direct) Bilirubin only → Urine में (water-soluble)	Fouchet's Test, Harrison's Spot Test
Urobilinogen (Urobilinogenuria)	Hemolytic Anemia, Hepatitis	Bilirubin → Urobilinogen; Absent in Complete Obstruction	Ehrlich's Test, Dipstick
Pus Cells (Pyuria)	UTI (Urinary Tract Infection)	Bacterial infection → WBC > 5/hpf in urine	Microscopy (> 5 WBC/hpf)
Casts	Renal disease	Protein/Cells solidified in tubules — Hyaline, RBC, WBC, Granular casts	Microscopy
Crystals	Renal Calculi risk	Uric Acid, Calcium Oxalate, Triple Phosphate	Microscopy + Chemical tests

C.4 महत्वपूर्ण Urine Tests — Qualitative

Test	Reagent	Positive Result

Benedict's Test	$CuSO_4$ + Na Citrate + Na_2CO_3	Brick-red precipitate = Reducing Sugars (Glucose)
Heller's Test (Protein)	Conc. HNO_3	White ring at junction = Albumin
Biuret Test (Protein)	NaOH + $CuSO_4$	Violet = Peptide bonds
Rothera's Test (Ketones)	Sodium Nitroprusside + NH_4OH	Permanganate purple ring = Acetoacetate/Acetone
Fouchet's Test (Bilirubin)	Trichloroacetic acid + $FeCl_3$	Blue-green = Bilirubin
Harrison's Spot Test (Bilirubin)	$BaCl_2$ + Fouchet's Reagent	Blue-green spot = Conjugated Bilirubin
Ehrlich's Test (Urobilinogen)	p-Dimethylaminobenzaldehyde	Cherry red = Urobilinogen
Guaiac Test (Blood)	Guaiac resin + H_2O_2	Blue = Hemoglobin (Peroxidase activity)
Gmelin's Test (Bile pigments)	Fuming HNO_3	Rainbow of colors = Bilirubin oxidation products

☆ Booster Points (D.Pharmacy Competitive Exam)

- ❖ Lymphocytes: T-cells (60–70%), B-cells (10–20%), NK cells (5–15%)।
- ❖ Lymphocytosis = Viral infections (EBV, CMV); Lymphocytopenia = HIV/AIDS।
- ❖ Platelets Normal: 1.5–4.0 $\times 10^5/\mu L$; Lifespan = 8–12 days (Megakaryocytes से)।
- ❖ Thrombocytopenia < 150,000/µL — ITP, DIC, Dengue, Aplastic Anemia।
- ❖ Sickle Cell Anemia: HbS (β-Globin Glu→Val) → Sickle-shaped RBC।
- ❖ Spherocytes → Hereditary Spherocytosis (Spectrin defect) → Osmotic Fragility ↑।

- ❖ Schistocytes → Microangiopathic Hemolytic Anemia, TTP, DIC।
- ❖ Howell-Jolly Bodies → Splenectomy, Megaloblastic Anemia।
- ❖ Basophilic Stippling → Lead Poisoning।
- ❖ Microcytic Hypochromic Anemia = Iron Deficiency (Most Common Anemia Worldwide)।
- ❖ Megaloblastic Anemia = Vit B12/Folate deficiency → Hypersegmented Neutrophils।
- ❖ Glycosuria: Blood Glucose > Renal Threshold (180 mg/dL) → Glucose in Urine।
- ❖ Ketonuria: DKA, Starvation → Rothera's Test Positive।
- ❖ Bilirubinuria: Only Direct (Conjugated) Bilirubin — water-soluble।
- ❖ Pyuria: WBC > 5/hpf → UTI। Harrison's Spot Test → Conjugated Bilirubin।

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